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New York State Museum

JOHN M. CLARKE, Director

Museum bulletin 123

IRON ORES OF THE CLINTON FORMATION IN NEW YORK STATE

BY

D. H. NEWLAND

AND

C. A. HARTNAGEL

ALBANY

UNIVERSITY OF THE STATE OF NEW YORK

1908

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New York State Education Department
Science Division, August 31, 1908

Hon. Andrew S. Draper LL. D.
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DEAR SIR: I have the honor to transmit herewith for publication as a bulletin of the State Museum, a report on the iron ores of central New York, prepared in pursuance of a provision in chapter 578, laws of 1907, "for determining what deposits of iron ore exist within the State of New York and the extent and availability thereof."

The investigations, the results whereof are here given, have been carried on by continuous drilling during the autumn, winter and spring of 1907–8 in a field where but slight effort has heretofore been made to estimate the volume of iron ore available for production. This report conclusively indicates that in the region of central New York there exists a commercial asset in iron of great magnitude and vast importance to the people of this State and the conclusions herewith set forth are in essential accord with the prediction made when it was recommended that the work be undertaken.

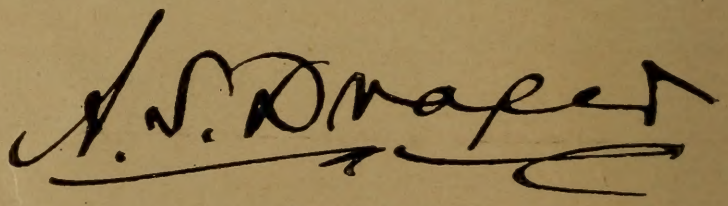
These operations have been carried on and the report prepared by D. H. Newland, Assistant State Geologist, and C. A. Hartnagel, Assistant in Economic Geology.

Very respectfully
JOHN M. CLARKE
State Geologist

State of New York
Education Department
COMMISSIONER'S ROOM

Albany, August 31, 1908

This is the report of the State Geologist covering a painstaking investigation of the extent of deposits of iron ore in the State, and having particular reference to the territory, something like one hundred miles in length, extending through the central part of the State, from Oneida and Otsego counties on the east to Wayne county on the west, for which a special appropriation was provided in the annual supply bill of 1907. Having very earnestly recommended the appropriation, I find much satisfaction in the assurance of the Geologist that a conservative estimate, based upon this investigation, of the quantity of iron ore deposited in this region places the amount at six hundred millions of tons. If this estimate is warranted, New York might yet easily become the leading iron state in the Union. Of course, this report is scientific and technical, but surely signifies much; and if it points the way truly, as the experience, attainments and assiduity of Dr Clarke, the State Geologist, warrant me in believing it does, it adds much to the economic resources, and is of much moment to the commercial prosperity of the State. The information it contains should be extended as quickly and as widely as practicable. Publication is approved and I hope it may be expedited.



Commissioner of Education

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IRON ORES OF THE CLINTON FORMATION IN NEW YORK STATE

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INTRODUCTION

The hematites accompanying the belt of Clinton strata in New York State have been worked commercially, though with some interruptions, since the early part of the last century. It is on record that a mining lease was granted in Oneida county as far back as 1797, and a small quantity of ore was shipped from Wayne county during the War of 1812. Regular mining operations were not instituted, probably, until about 1825. A few years later charcoal forges and furnaces had been erected in Wayne, Madison and Oneida counties, as reported by the geologists connected with the Natural History Survey of the State.

The production of Clinton ores has averaged about 75,000 tons for the last few years. In 1907 it was 109,025 tons. The aggregate from the beginning may be placed at from 4,000,000 to 5,000,000 tons, which is approximately the yield obtainable, with the average workable seam, from a square mile of area. Mining has been restricted entirely to the surface portion of the beds, and little or nothing has been done by the mine interests, hitherto, toward exploration outside the limited fields of operations.

By the present investigation it is hoped to anticipate, so far as may be, the need for a practical guide to the development of these deposits. With the aid of a legislative appropriation, specially granted for the purpose, it has been possible to perform a series of exploratory tests with the diamond drill and, from the results thus secured, to gain for the first time a general view of the ore distribution over a considerable section of the Clinton belt. A detailed account of this work is included in the report.

The resources of the Clinton formation, known to exist within easy reach of mining operations, are so extensive that they seem to offer a promise of increased commercial importance for the future. The principal handicap to the use of the ores, hitherto, has been their relatively low iron content — from 35 to 45%. But with the rapidly growing demand made upon other eastern mining fields — which has been reflected by a steady falling off in the quality of the product in most cases — its effect is now much less apparent than formerly and will be subject, doubtless, to further reduction. A factor of considerable importance, also, in this connection is the fluxing nature of the Clinton ores, which counterbalances to an appreciable extent their deficiency of iron when used in the furnace.

Because of the unusual interest which is being manifested in the deposits, it has been deemed best to make the results of the investigation public at an early date. To that end some matters of more remote economic application have received scant attention or have been omitted altogether from the discussion, though they might properly come within the scope of the report. The recent field work and exploration have brought out much that is new concerning Clinton stratigraphy and shown the need for a more thorough study of the New York section, to our knowledge of which little has been added since the reports of Hall and Vanuxem. The relations of the formation to its associates, particularly, are open to inquiry. For the present nothing further can be done than to indicate some important corrections and to record observations on which such restudy may be based.

For cooperation in the preparation of the report it is desired to express grateful acknowledgment to the mining and development enterprises and owners of ore properties, who have always given a ready response to inquiries and have extended many other courtesies during the field and office work. The report has specially benefited by the assistance of Mr Charles A. Borst of Clinton, who

contributed many facts relating to ore localities and mines in Oneida county, and of Mr H. M. Selleck and Mr Freeman Pintler of Ontario, who furnished much information about the ores of Wayne county. The line drawings accompanying the report have been made by Mr H. P. Whitlock.

PREVIOUS STUDIES

The researches of Hall and Vanuxem in connection with the first Geological Survey of New York State have been the source of most of our knowledge concerning the Clinton formation. The descriptions of its bounds and relations, as set forth in their final reports of 1842–43, have undergone no essential amendment to this day and are still standard for the recognition and comparison of the different Clinton occurrences elsewhere.

Previous to their investigations, Amos Eaton had given a brief account of the ores and associated beds in his monograph, *A Geological and Agricultural Survey of the District adjoining the Erie Canal.* Eaton seems to have visited the outcrops along the belt at intervals from Herkimer county to the Niagara river. The hematites are placed in the class of "secondary ferriferous rocks," which are stated to consist principally of slate and sandstone. It is not always possible to recognize the various members referred to by Eaton, though there is little doubt that the class includes parts of the Medina and Rochester formations, as now understood, in addition to the Clinton beds.

Vanuxem, whose field of work was in the central part of the State, first described the Clinton and Niagara representatives under a single group which he called Protean. It was later found that the upper and lower members were of unequal distribution, the latter having their strongest development in the eastern section, while the former were predominant in the west. The group accordingly was subdivided. The name Clinton was given to the lower part, from the village of Clinton, Oneida co., and as a "tribute to one who spared no effort to extend a knowledge of science and to add to its acquisitions." The outcrop of the strata was traced by Vanuxem as far west as Cayuga county.

In the final report by James Hall, covering the western section of the Clinton, the following subdivisions are recognized, in ascending order: 1 Lower green shale: 2 Oolitic or lenticular iron ore; 3 Pentamerus limestone; 4 Second green shale, with

second iron ore bed; 5 Upper limestone. The exposures of iron ore existing at the time are recorded in detail by both Hall and Vanuxem whose reports, also, are replete with information relating to the character, thickness and other features of the beds.

The portion of the Clinton belt included in the limits of the Rochester quadrangle, about 13 miles from east to west, has been mapped by C. A. Hartnagel. The map is on the usual scale of the folio sheets (1 mile to the inch) which are in preparation for the whole State. In the report accompanying the map the five subdivisions of Hall are described under the local names: Sodus shale, Furnaceville iron ore, Wolcott limestone, Williamson shale, Irondequoit limestone.

The papers by C. H. Smyth jr, contain an accurate and exhaustive exposition of the origin of the Clinton ores — by far the most satisfactory that has appeared. The evidences Professor Smyth has brought to bear upon the question, from the standpoints of geology and chemistry, must be convincing to any one familiar with the local deposits. For these, at least, the view of secondary replacement which has been advanced by some geologists, may be regarded as completely disproved. A discussion of the subject of origin, with a statement of Professor Smyth's views, is given in a subsequent chapter.

DISTRIBUTION OF THE CLINTON FORMATION

The Clinton strata — comprising shales, limestones, sandstones and interbedded layers of iron ore — are found in a single belt which extends from the eastern central part of the State to the Niagara river and thence for some distance into the Province of Ontario. The length of the belt, included within the limits of the State, is about 225 miles.

On the east the strata can be traced into Otsego county, where they thin out to disappearance, though they were formerly supposed to continue southeasterly into Schoharie and Albany counties. From field observations made recently by one of the writers (C. A. Hartnagel) it would appear that they terminate in the town of Cherry Valley, a short distance east of Salt Springville. This is undoubtedly the limit of their deposition in eastern New York.

West from Otsego county the Clinton belt passes successively through Herkimer, Oneida, Madison, Onondaga, Oswego, Cayuga, Wayne, Monroe, Orleans and Niagara counties; it


MAP SHOWING
POSITION AND EXTENT
OF THE
OUTCROP OF THE
CLINTON FORMATION
IN
NEW YORK
LAKE ONTARIO
LAKE ERIE
Kingston
Port Hope
Toronto
St.Catherine
Port Colborne
Lockport
Albion
Medina
ROCHESTER
BUFFALO
Batavia
Lyons
Syracuse
Oswego
Watertown
Lowville
Rome
Utica
Herkimer
Auburn
Canandaigua
Geneva
Penn Yan
Ithaca
Watkins
Elmira
Corning
Bath
Cortlandt
Norwich
Cooperstown
Binghamton
Owego
Delhi
Jamestown
Olean
Salamanca
Dunkirk
Mayville
Warsaw
Dansville
Belmont
ORLEANS
NIAGARA
MONROE
WAYNE
GENESEE
WYOMING
ONONDAGA
CAYUGA
SENECA
YATES
SCHUYLER
TOMPKINS
CORTLANDT
CHEMUNG
TIOGA
BROOME
STEUBEN
ALLEGANY
CATTARAUGUS
CHAUTAUQUA
OTSEGO
DELAWARE
JEFFERSON
LEWIS
ST. LAWRENCE
ONEIDA
ONEIDA LAKE

crosses the Niagara river at the falls and comes to an end probably in the Province of Ontario. The Clinton areas of Ohio and Wisconsin seem to have been formed in basins separate from the above.

The width of the outcropping strata as shown on the maps ranges up to a maximum of about 5 miles. It is greatest in the central part, in the vicinity of Oneida lake and immediately westward. It diminishes very gradually away from that section, specially to the west, where the strata continue for a long distance with scarcely perceptible changes. The outcrop narrows more quickly toward the east mainly on account of the increasing inclination of the beds in that direction.

The restriction of the Clinton strata to the single belt above delimited is not in accordance with the work of the early geologists, generally accepted until recent years, but it has the support of most convincing evidence. The beds in Schoharie and Albany counties that were formerly supposed to represent the eastern continuation of the belt are now known to be of much later (Salina) age. Likewise the areas in the Skunnemunk and Shawangunk mountains of Sullivan and Orange counties, some 60 miles long altogether, assigned to the Clinton in the early reports, have since been demonstrated to be of post-Clinton development.

TOPOGRAPHIC FEATURES

The Clinton outcrop is seldom traceable by the surface configuration. Physically and structurally united to the beds above and below, the formation has developed few topographic features, by weathering or erosion, that are distinctive.

In the extreme west the Clinton strata are involved in the Niagara escarpment of which they constitute the median portion as exposed in the Niagara gorge. Passing eastward the escarpment become less prominent as a scenic feature and practically disappears in the vicinity of Rochester. The soft shales have been denuded so as to yield a gentle slope from the level of the Lockport limestone at the top down to the Ontario plain that is floored by Medina sandstone. The outcrop of the formation widens out, of course, with the flattening of the topography.

At Rochester the Clinton strata are crossed by the Genesee river which occupies a deep gorge at this point, causing a V-shaped upstream deflection of the outcrop. This is the only place east of the

Niagara gorge where the strata are exposed from the base to the top. Five miles farther east the depression occupied by Irondequoit bay causes another deflection in which the beds are bent in a long loop toward the south.

Beyond Irondequoit bay the basal members of the Clinton spread out northward and cross the "Ridge road," a conspicuous terrace which marks the old shore line of the glacial Lake Iroquois. Their northerly outcropping edge parallels this shore line, about a mile distant, as far as Sodus, Wayne co. Between Sodus and Verona, Oneida co., an embayment of Lake Iroquois extended southward into the Finger Lake region and the entire Clinton between these localities is included within the old lake basin.

In the section from Sodus to the Oswego river, drumlins form a prominent feature of the topography, whereas to the west they are but little developed in the vicinity of the Clinton belt. Their presence conditions the great variation in the amount of overburden encountered in this part, which may reach a thickness of 100 feet or more. They have the usual elongated oval shape, with the main axis parallel to the direction of the ice movement, which was about north and south. They attain an average length of a mile, and some of the more rounded ones are half that in width. Their distribution is irregular, closely set and overlapping at the bases in some places and again spreading out so as to leave an intervening stretch of level country. There are few exposures of the underlying rocks, chiefly along the streams that wind through the connecting depressions.

In the Oneida lake region, the Clinton formation crosses a very flat part of the Iroquois basin. The surface is composed mostly of clays and sands that have been washed over and leveled by wave action. The thickness of these materials is inconsiderable, though few rock outcrops occur.

After entering Oneida county, the trend of the formation, hitherto nearly east and west, bears gradually to the south until it is about 30° south of east. From Verona to Hecla Works, the country is still comparatively level, but loses this character as the Mohawk river is approached, near which the formation becomes involved in the range of hills that limits the valley on the south and merges gradually with the higher ranges of the Helderbergs, so as to present an uninterrupted highland extending eastward into Albany county.

GENERAL GEOLOGY

Stratigraphic relations of the Clinton formation

The Clinton formation falls within the middle division of the Upper Siluric or Ontaric system. At the base of this system, as constituted in New York, lies the Oswegan group which includes the Medina and Oswego sandstones and the Oneida conglomerate. The middle or Niagaran group consists of the Clinton at the base, followed by the Rochester shale and the Lockport and Guelph dolomites. The upper or Cayugan group is made up, in ascending order, of the Salina, Cobleskill, Rondout and Manlius formations. The succession is shown in the following table:

ERA OR SYSTEM	PERIOD OR GROUP	AGE OR STAGE
Ontaric or Upper Siluric	Cayugan	Manlius limestone
		Rondout waterlime
		Cobleskill limestone
		Salina beds
	Niagaran	Guelph dolomite
		Lockport dolomite
		Rochester shale
		Clinton beds
	Oswegan	Medina sandstone, including the Oswego sandstone and Oneida conglomerate

In tracing the Upper Siluric formations across the State it has been found that the higher members have a greater linear extent than the lower ones. This is due to a progressive overlap in sedimentation, whereby each member has had a wider area of deposition than the one immediately preceding. The general relations will be readily understood from the accompanying diagram. It will be observed that there is one exception to the statement above in regard

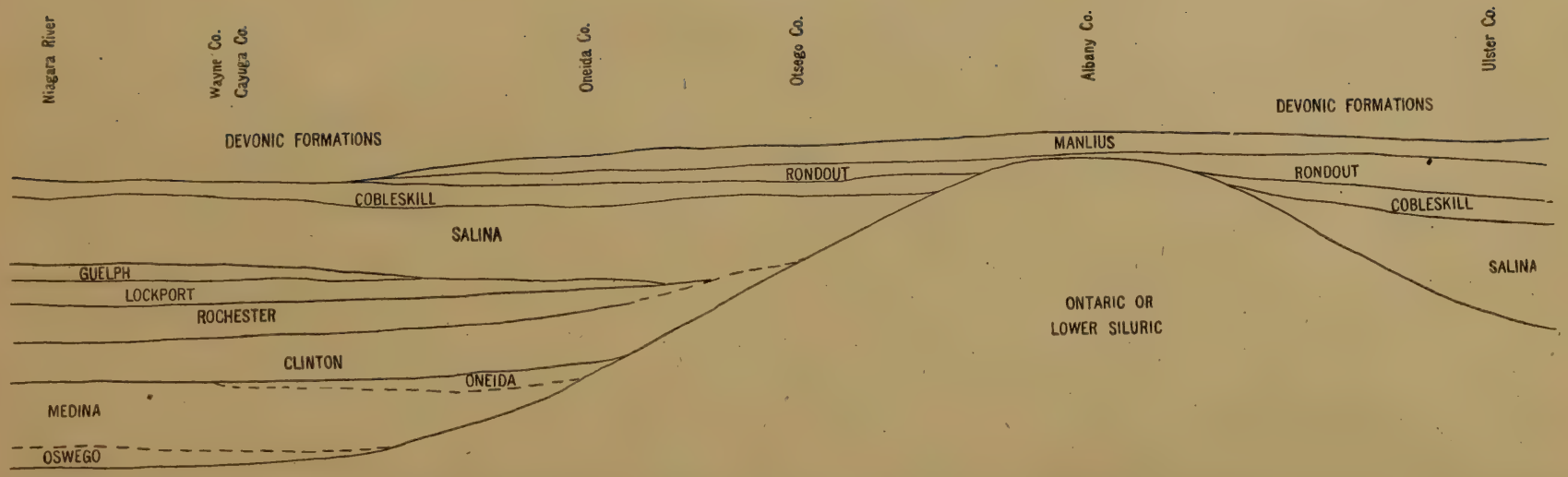


Fig. 1 Diagram showing relative position and linear extent of the Upper Siluric formations in New York State, and their relation to the Lower Siluric and Devonic

to overlapping of the strata, due to a slight uplift which seems to have occurred at the close of the Clinton age. The effect of the uplift is apparent in limiting the transgression of the Niagaran sea to the east, causing the disappearance of the upper members in that direction and bringing the Salina into contact with the Clinton beds.

The whole series of Upper Siluric strata of central and western New York from the Medina up to and including the Niagaran group was laid down in the great mediterranean, known as the Mississippian sea, which came into existence probably during Cambric times. The sea was shut off from the Atlantic basin by a broad barrier that extended along the Appalachian protaxis from New Brunswick through New England, eastern New York and the intervening states to northern Alabama and connected on the north with the continental old-land or Laurentia of Canada. At the opening of Upper Siluric time the barrier had assumed increased proportions through the Taconic revolution. The sediments which had accumulated along the shore of the Appalachian and Canadian regions during Cambric and Lower Siluric times were upraised and folded. Thus, the entire eastern section of New York State became land. Following this uplift the interior sea began to extend its limits so that the Upper Siluric deposits encroached more and more upon the land surface to the east.

With the Cayugan period, sedimentation took place again in southeastern New York. Representatives of this group are found across the State from the Niagara river to Albany county. Here their line of outcrop bends to the south, passing into Ulster county, and thence southwest through Sullivan and Orange counties and into New Jersey in the vicinity of Port Jervis. Disconnected areas, constituting outliers of the main belts, are met with in Orange county, running southwest from the Skunnemunk mountain region. These outliers consist of conglomerate of Salina age (the Shawangunk conglomerate of New York State and the Green Pond conglomerate of New Jersey) followed by a series of sandstones, shales and limestones. Formerly the series was considered to belong to an earlier period of deposition, the conglomerate having been taken for the equivalent of the Oneida in central New York and some of the overlying beds for the Clinton.

The Upper Siluric beds follow each other in conformable arrangement. After the Taconic upheaval sedimentation appears to have been continuous during the whole of the following era. The

Taconic disturbance is most apparent in the eastern part of the State where there exists a strong erosional unconformity between the Lower and the Upper Siluric that is well marked also by basal conglomerates (Oneida, Skunnemunk and Shawangunk); its apparent influence can not be traced farther west than Oswego county, as Vanuxem[1] has noted that no break occurs in the succession from the Lower Siluric to the Oswego sandstone of that section.

The Upper Siluric formations, for the most part, have the characters of shallow water accumulations. In the basal members sandstones and conglomerates prevail and are made up of the coarser quartzose detritus from the wash of the nearby land. Some finer sands and muds were brought down and deposited during Medina time to form the shales which are interbedded with the sandstones, but it was not until Clinton time that they came to be the predominant material. During this and the succeeding Rochester ages silts were accumulated in great thickness, though there were brief periods in the Clinton when they gave way to limestones and in eastern New York to calcareous sandstones. With the beginning of Lockport time the conditions of sedimentation became favorable to the deposition of limestones and these rocks were laid down all through the rest of the Upper Siluric, with one notable interruption represented by the Salina shales. The changes in the character of the sedimentation are to be regarded, doubtless, as reflecting a certain amount of coastal oscillation which produced shallowing or deepening of the waters adapted to the different deposits. It is not necessary to suppose, however, that the shales and limestones required any great depths for their accumulation. On the other hand there are unmistakable evidences that they were laid down for the most part within the littoral reign. The Clinton and many of the overlying limestones are of fragmental character, composed of fossils that were washed up on the old beaches where they were worked over and ground by wave action. Abundant beach markings, such as ripple marks, shrinkage cracks, worm borings and tracks of crustaceans are to be found in the shales.

During Clinton time there seems to have been an approach to the conditions which later in the Salina age led to the extensive deposition of salt and gypsum. These conditions may have been initiated even as early as Medina time. Salt springs are found not infrequently along the outcrop of the Medina sandstones and in such a state of concentration that they were once used commercially for

[1] Geol. N. Y. 3d Dist. 1842, p. 61 *et seq.*

the extraction of salt. Their presence, even if not due to included beds of rock salt, which so far have never been discovered, indicates a high degree of salinity for the waters, that is likely to have been brought about by evaporation in basins shut off from free communication with the sea. The deposition of the Clinton hematites required a similar concentration, as will be explained later in the discussion of their origin.

The existence of shallow waters, sheltered bays and lagoons requisite to the accumulation of deposits like those characteristic of the Clinton formation may be considered as indicative of an extensive coastal plain stretching southward from the ancient land masses — the Laurentian and Adirondack areas. Such a coastal plain had been built up from wash of the lands during the long interval from Potsdam to Medina time. During the Medina age there must have been a gradual sinking of this platform with the progress of sedimentation, and the subsidence continued into Clinton time, though not on the same scale.

As to the northern limits of the shore line during Clinton time, there is little information to be gained from present conditions. Since the uplifting of the strata, they have been continuously subjected to erosion and their outcropping portions worn back until they are now considerably south of the original limits. It seems scarcely probable, however, that the Clinton beds ever extended so far north as to overlap on the crystallines, since this would involve the removal of more than 100 miles of rock on the western end of the belt, between the present line of outcrop and the southern edge of the Canadian Precambric area.

The materials of which the Clinton strata are composed were derived ultimately from the Precambric crystallines. A small portion may have been furnished by the Paleozoic sediments fringing the crystalline areas and previously upraised above sea level. But as these sediments are for the most part low in iron, it is to the Precambric gneisses and schists with their relatively high iron content and extensive iron ore deposits that we must look for the source of the Clinton hematites. The only sedimentary strata of the lower Paleozoic that contain appreciable percentages of iron are the Medina and Potsdam sandstones. The crystalline rocks, on the other hand, uniformly carry several per cent of iron oxids, both free as magnetite and combined in the silicate minerals, and in the Adirondack region they inclose important bodies of magnetite, hematite and pyrite.

The ferruginous minerals were set free from the containing rocks by the processes of weathering and denudation which were operative during a vast time interval. The Adirondack region existed as a land area throughout the latter part of the Precambric and all of the Cambric eras. In the Lower Siluric era it was depressed and encroached upon by the sea, but with the Taconic revolution it was again upraised to remain as a land surface to the present time. The weathering sufficed to break up the ferromagnesian constituents, the iron going into solution, while the magnetite and pyrite were also changed more or less completely into soluble compounds. Very little magnetite and none of the original pyrite are found in the early sediments formed from the decay of the crystallines. While it appears reasonable that the magnetite may have been brought down partly as sand and subsequently altered to hematite, producing the red sandstones of the Potsdam and Medina formations, there is much reason for believing that the Clinton ores were deposited from solution in which the iron existed for the most part as ferrous carbonate but to some extent possibly as sulfate. The conditions under which the ores were formed are set forth more fully in a subsequent chapter.

General structure

The Clinton beds are uniformly inclined toward the south, the direction of slope of the original coastal plain on which they were deposited. Their uplift from sea level seems to have taken place gradually and with little disturbance of their relative position. They are nowhere displaced by faults, apparently, and only in a broad way, as will be explained later, can they be said to show evidences of flexure.

The lowest dips are encountered in the central portion of the belt, in Wayne and Cayuga counties. From the records of the deep wells driven south of the outcrops, it has been possible to determine the dips for this section with great exactitude. Beginning in the central part, along the meridian of middle Wayne county, the strata have an inclination amounting to 820 feet in the 18 miles from the Alloway well to the outcrops on Second creek, or an average of 45 feet to the mile. In the 13 miles from the Clyde well to the line of outcrop due north, as near as it can be located, the aggregate is 640 feet or 49 feet to the mile. Between the well at Seneca Falls and the Wolcott exposures, a distance of 25 miles along the meridian, the average is 48 feet to the mile. From the Auburn well to Sterling Station on a line slightly west of north the mean dip for the 25 miles is 51 feet to the mile.

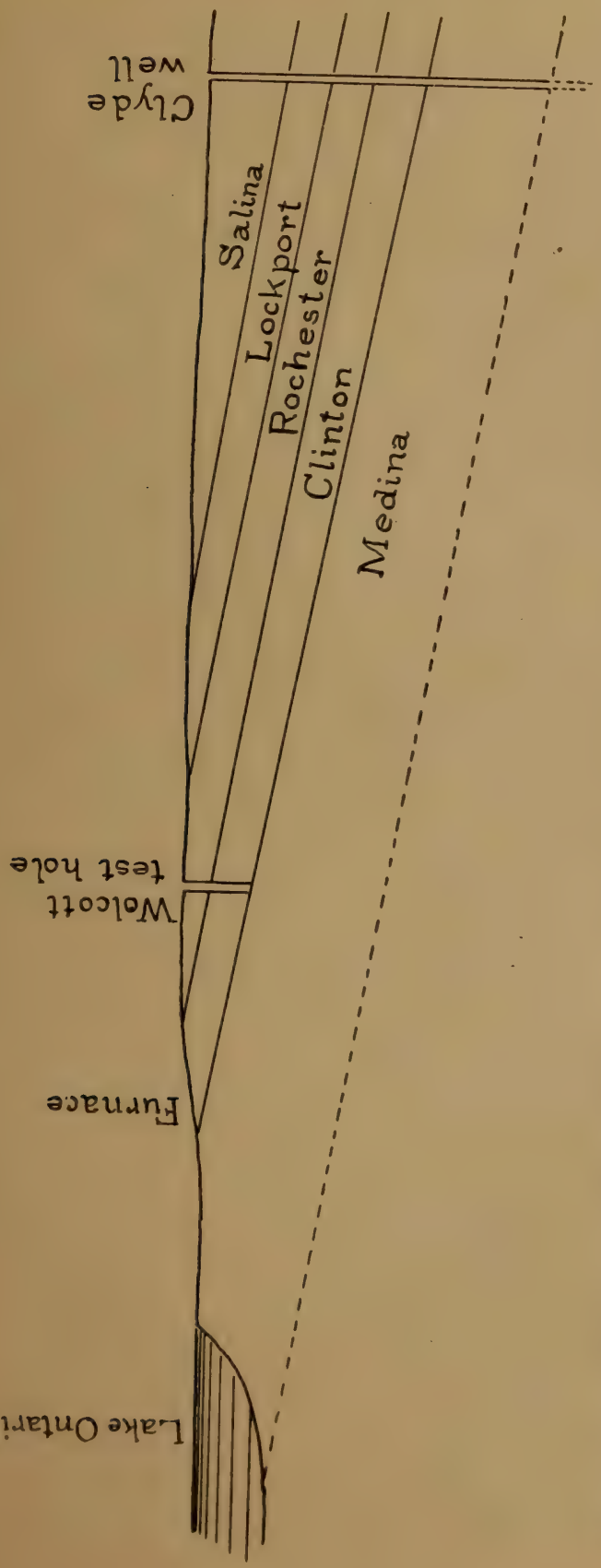


FIG. 2 Ideal section across the Upper Siluric in eastern Wayne county. The actual inclination of the strata is much less than indicated, amounting to about 50 feet to the mile.

In Erie county on the western end of the belt the dip of the Upper Siluric strata has usually been estimated at 50 feet or less to the mile. The Clinton outcrop, however, here lies fully 150 feet higher with respect to sea level than it does in the central part, a circumstance that seems to indicate a higher rate of inclination than the above, when it is further considered that the line of outcrop is somewhat south of its position in Wayne and Cayuga counties. At Rochester the dip has been stated at 80 feet to the mile, in a direction slightly east of south.

On the eastern section of the belt the dips increase progressively from Madison to Herkimer county, while there is likewise a gradual increase of elevation of the outcrop. The average dip, as determined from the Chittenango and Lakeport wells, in Madison county, is 62 feet to the mile over a distance of 8 miles. The dip of the iron ore at Clinton as determined by leveling is 150 feet to the mile. There is little basis for calculation of the dips in the part of the belt beyond Oneida county, but it is to be expected naturally that the beds are more highly inclined as they come more and more within the zone of the Appalachian uplift.

It is in this region that the Clinton outcrop reaches its highest elevation which is about 1400 feet. At Clinton the elevation is about 700 feet. In eastern Wayne county the iron ore bed lies at nearly the level of Lake Ontario which is 246 feet. In Niagara county the northern outcropping edge of the Clinton is found at about 400 feet.

A comparison of the dips given above shows that the uplifting of the beds has been accompanied by a certain amount of warping, the effect of which has been to give the formation as a whole a broad synclinal arrangement, with the depressed portion in the central part near the Wayne-Cayuga county line, where the beds attain their most northerly extent within the State. East of this line the general dip is toward the southwest, becoming more marked as the eastern termination is approached. Between Cayuga and Monroe counties the dip is slightly east of south. West of Monroe county the syncline appears to be interrupted by a minor undulation, indicated by the southwesterly dip of the beds at Niagara Falls.

Details of Clinton stratigraphy

The name Protean originally applied to the Clinton beds by Vanuxem is significant of their extreme variability. They comprise a heterogeneous assemblage of sedimentary types that show little uni-

formity from place to place. Frequent changes in lithic character, thickness and faunal contents are observable throughout their extent in New York State.

In Niagara county, on the western end of the belt, limestone with a smaller amount of shale constitutes the entire formation. Passing through Orleans into Monroe county where the beds are again well exposed, it is found that the shale predominates over the limestone, a relation which holds true in a general way throughout the remainder of the distance to Herkimer county. In Monroe county the first hematite seam is encountered in outcrop, though it probably begins farther west. In Wayne and Cayuga counties there are important changes with respect to the relative development of the shales above and below the lower or main ore bed, while a second hematite stratum accompanied by limestone makes its appearance. Duplication of the ore seam is a common feature from here to Oneida county. Within the interval included by Oswego, Onondaga and Madison counties the shales attain even greater relative strength, compared with the limestone. Throughout the middle part of the belt, from Wayne to Madison counties, the lower ore bed lies but a few feet above the Medina formation. In Oneida county, however, there is a very appreciable thickening of the basal green shale which causes the ore to lie from 40 to 100 feet over the Medina. Toward eastern Oneida county, the shale becomes quartzose, grading into thinly bedded sandstone with shaly layers.

From Oneida county the stratigraphic bounds of the formation are somewhat indefinite. It is particularly difficult to establish the upper limits, since the extent of the Rochester beds above has not been definitely ascertained. Recent paleontological investigations around Clinton and east of there seem to indicate that the sandstone and shale beds heretofore regarded as upper Clinton may belong to the Rochester. The strata in Herkimer county are closely involved at the base with the Oneida conglomerate and the exact line of demarcation between them has not, as yet, been satisfactorily determined.

The stratigraphic succession along the belt will be shown more in detail by a number of sections that have been prepared from exposures and records of drill borings. The sections are given in order from west to east. Attention may be called here to the records of the test holes recently put down in the portion of the belt from Wayne to Oneida county given in detail in the chapter relating to exploration.

Niagara river. The Clinton strata are exposed within the Niagara gorge all the way from the falls to Lewiston at the north end. They are overlain by 70 feet of Rochester shale and rest upon the "gray band" that forms the uppermost layer of the Medina.[1] Their aggregate thickness is 32 feet.

STRATA	FEET
Bluish gray limestone, somewhat crystalline, fossiliferous.	12
Compact limestone, few fossils, carries iron pyrite in lower portion, the only semblance of the iron ore seams farther east	14
Bright green and olive shale	6

Rochester. Between Niagara river and Rochester, a distance of 75 miles, no complete sections of the Clinton are available. At Rochester the Genesee river cuts through the entire formation, affording one of the best exposures along the entire belt.

STRATA	FEET
Bluish gray limestone (Irondequoit), crystalline, abundant fossils in certain parts	18
Green shale (Williamson) with dark bands containing graptolites and pearly bands near top with *Anoplotheca hemispherica*	24
Hard limestone (Wolcott), silicious, holding *Pentamerus oblongus*, commonly known as Pentamerus limestone	14
Iron ore (Furnaceville), fossil hematite	14 in.
Green shale (Sodus), few fossils	24

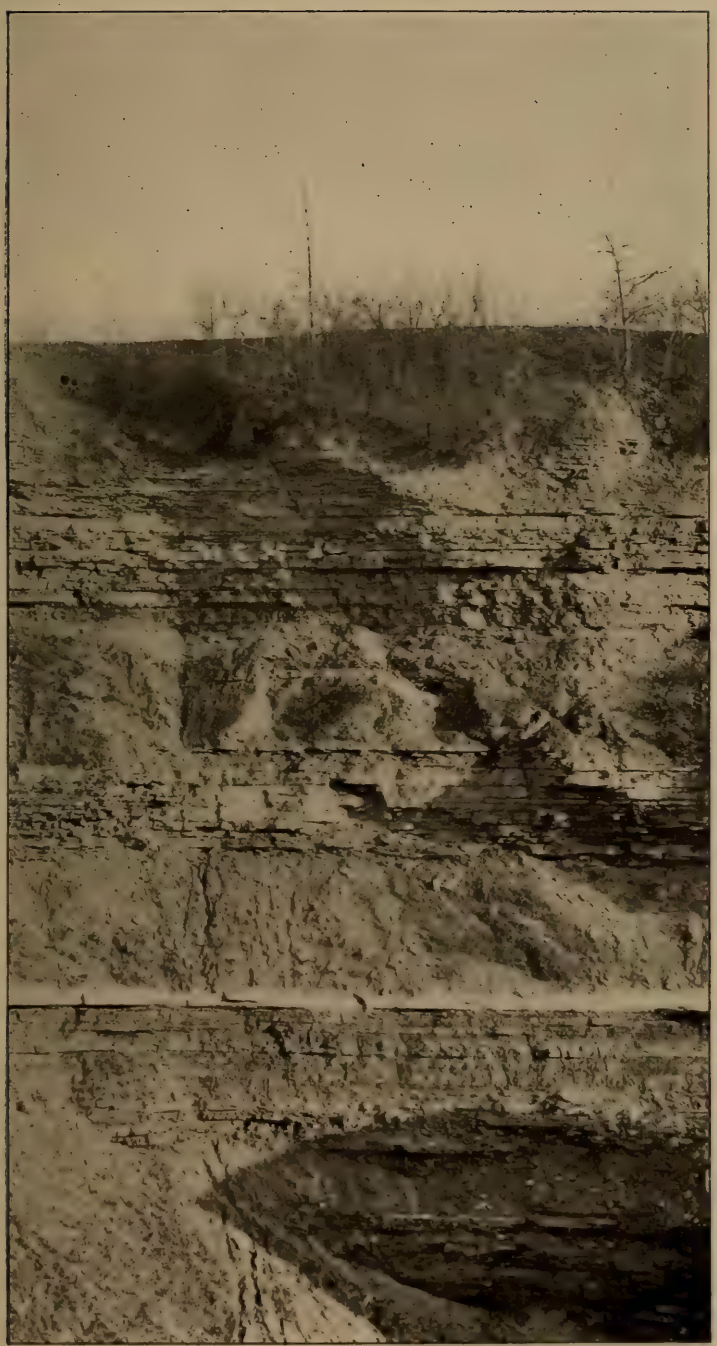
The formation is here 81 feet thick, a gain of 49 feet over the thickness shown at Niagara Falls, mostly represented in the shale members [*see* pl. 2].

Ontario, Wayne co. From the mine workings and drill holes near Ontario, 15 miles northeast of Rochester, the following succession has been established for the lower members of the formation.

STRATA	FEET
Soil and gravel	10+
Shale (Williamson) grading into limestone below	2

[1]For fuller description of the Niagara Falls section, Grabau, N. Y. State Mus. Bul. 45. 1901.

Plate 2



Genesee gorge, Rochester, showing the upper Medina, the Clinton beds and the base of the Rochester shale

STRATA	FEET
Limestone (Wolcott), with abundant Pentamerus	8
Iron ore, fossil	22 in.
Green shale (Sodus) compact, calcareous	10±
Medina shale	....

Wallington, Wayne co. From the test hole put down at this locality, the following condensed section has been prepared. The full details are given in the part of the present report relating to the recent exploration. The section is introduced here for the purpose of elucidating the stratigraphic relations in this region which have not, heretofore, been satisfactorily explained.

STRATA	FEET
Limestone	10
Dark shale, with graptolites	36
Pentamerus limestone	14
Shale, thin bedded, with few fossil varieties	54
Pentamerus limestone	13
Ore, fossil	1
Limestone	1
Ore, fossil	8 in.
Green shale, calcareous	5
Medina shale	2+

The total thickness of the Clinton shown in the hole is 135 feet, an increase of 54 feet over the amount at Rochester.

It will be observed that there are two beds of the Pentamerus limestone, separated by 54 feet of shale. In the early reports this duplication of the limestone was not recognized, which led to a misinterpretation of Clinton stratigraphy in the eastern half of Wayne county. The main or lower ore horizon, indicated by the two seams in the above section, occurs just below the first limestone bed, a position that is constant throughout Wayne county. There is in some places a third ore seam immediately above the upper Pentamerus limestone. This is shown on Second creek, near the entrance to Sodus bay, a little way east of Wallington, a locality referred to by Hall as the Shaker settlement. From study of the Second creek exposure Hall expressed the opinion that the limestone there was identical with the lower Pentamerus and that the iron ore bed found above it was the only one in that locality. It is now certain that there are two ore horizons, the lower being concealed, as its line of

outcrop brings it beneath Sodus bay. In the same way Hall identified the ore bed at Wolcott furnace with the seam opened to the east and recently worked at Sterling Station, while they are really two different beds separated by from 75 to 100 feet of shale.

Clyde, Wayne co. A deep well was put down in 1887, in the village of Clyde, about 13 miles south of the Clinton outcrop. The altitude at the mouth of the well is given by Prosser,[1] from whose paper the record has been taken, as 389 feet. The boring was made with a churn drill. The iron ore reported is near the top of the Clinton and represents probably the upper ore horizon.

STRATA	FEET
Gray, green and blue marls (Salina)	152
Red marls (Salina)	156
Blue and green marls (Salina)	32
Dark blue limestone, dolomitic (Lockport)	110
Shaly limestone (Rochester)	225
Shale and limestone, first 15 feet reddish with iron ore (Clinton)	83
Red shale (Medina)	24
Sandstone (Medina)	3

The well was continued into the Hudson River beds, reaching a total depth of 1792 feet.

Alloway, Wayne co. In 1899 a deep boring was made at Alloway, 18 miles south of the Clinton outcrop and 8 miles southwest of the Clyde well at an altitude of 410 feet.[2] The well was started in the Salina and the Niagaran group was reached at 580 feet. No data were obtainable as to the Clinton beds, but they must have been penetrated above 980 feet where the first Medina was found.

Seneca Falls, Cayuga co. A deep well was put down at this place, which is 12 miles southeast of Clyde and 25 miles south of the Clinton outcrop near Wolcott.[3] After penetrating the Salina formation, the Niagaran strata were encountered at 950 feet. The combined thickness of the Clinton, Rochester and Lockport beds, which are not differentiated in the records, is given as 400 feet. The top of the Medina was encountered at 1350 feet. The altitude of the mouth of the well is 385 feet.

[1] Am. Geol. 1890. 6: 203.
[2] C. S. Prosser. Am. Geol. 1900. 25: 353.
[3] Prosser. Am. Geol. 1890. 6: 203.

Wolcott, Wayne co. The section of the Clinton at Wolcott, condensed from the record of the recent test hole, is as follows.

STRATA	FEET
Shaly limestone	13
Dark colored shale, with graptolites	44
Ore, fossil	1
Pentamerus limestone	22
Shale	62
Shaly limestone, lower Pentamerus	13
Ore with limestone seam	2
Shale	2+

The drill did not penetrate through the lowest Clinton shale which probably extends 3 or 4 feet below the bottom of the hole. Estimating the thickness of this shale at 6 feet, the Clinton beds aggregate 164 feet, as compared with 135 feet at Wallington.

The upper hematite seam here shown must disappear within a comparatively short distance to the east, since it was not found in the hole at Red Creek. It is present, however, just north of Alton, on Second creek, 10 miles west of Wolcott, but thins out entirely before Wallington is reached. The lower Pentamerus limestone is here quite shaly, containing fewer fossils than farther west. East of Wolcott it is scarcely recognizable. The limestones generally become less important after the belt passes Wayne county. Throughout the eastern part they never form solid masses of any size but are always in thin layers with shale intercalations.

Red Creek, Wayne co. The test hole at this place was drilled to a depth of 178 feet before reaching the ore horizon. The section of the Clinton may not be complete. The greater part of the hole was in shale, with limestone between 86 and 103 feet, representing, perhaps, the upper Pentamerus. About 2 feet of limestone, representing the lower Pentamerus, was found just above the ore. The complete record is given elsewhere.

Auburn, Cayuga co. A deep well was drilled during 1897–98 about 1½ miles north of Auburn. The locality is 24 miles south of the Clinton outcrop at Fair Haven. The strata assigned to the Clinton by Prosser[1] consisted of green noncalcareous shale, 10 feet, and clear green argillaceous shale, 115 feet. Since no samples were inspected from 1290 feet when the drill was in Lockport limestone

[1] Am. Geol. 1900. 25: 157.

to 1380 feet where the green noncalcareous shale was met, it is likely that the top of the Clinton was missed and that the beds are only partly represented in the aggregate of 125 feet above given.

South Granby, Oswego co. A nearly complete section of the Clinton formation was afforded by the test hole put down at South Granby, 15 miles east of Red Creek. An abridged record is given below. The drill started in Rochester shale, which became limey below, grading apparently into the Clinton limestone.

STRATA	FEET
Limestone	1½
Shale, with 4 inches of limestone at 102 feet depth	95
Light colored limestone, with traces of hematite	1
Shale, with 3 inches of iron ore	4
Limestone, basal part shaly	14
Shale, with limestone bands	69
Ore, oolitic	8 in.
Mottled shale	4

The lowest shale was not drilled through, but its base is probably not more than a foot or so below the bottom of the hole. The aggregate thickness is 190 feet.

Brewerton, Onondaga co. The test hole drilled at Brewerton afforded a partial Clinton section of 130 feet.

STRATA	FEET
Olive shale, with 2 inches of fossil ore at 56 feet depth and thin limestone bands at intervals	124
Ore, oolitic	16 in.
Sandstone and shale	5

From outcrops in the vicinity it is judged that the shale above the ore must be at least 150 feet thick. The drill was placed near the lake level and passed through 14 feet of clay before the shale was reached.

Syracuse. Two deep wells were drilled in 1884 near Syracuse. One, known as the Gale well, was put down 3 miles northwest of Syracuse near Onondaga lake and a little way east of the Oswego canal. The altitude at the mouth of the well is given as 435 feet. The record was reported by Dr F. E. Englehardt.[1] The Salina shales were penetrated to a depth of 525 feet, followed by the

[1] Annual Report of the Superintendent of the Onondaga Salt Springs, 1884.

Niagaran strata. Oolitic hematite was encountered at 976 feet and continued, according to the record, till 986 feet. The passage from the Clinton into the Medina strata was taken at 1007 feet depth and according to Prosser's interpretation at 991 feet. On the latter basis the combined thickness of the Clinton, Rochester and Lockport beds amounted to 466 feet. The second well, known as the State well,[1] was drilled a short distance southeast of the Gale well. The record given by Dr Englehardt does not vary essentially from the preceding, so far as the Clinton is concerned. The ore bed was encountered at 995 feet, with an estimated thickness of 5 feet.

Chittenango, Madison co. This is the site of a deep well which was drilled in 1890. The altitude at the top of the well is estimated at 444 feet. Prosser[2] gives the Clinton as beginning at 567 feet depth, with a green argillaceous shale 33 feet thick. Below this is bluish gray shale, 44 feet. Then follows dark gray calcareous material with iron ore, 11 feet, and at the base green argillaceous shale, 235 feet; the lower 10 feet having "a few reddish chips like iron ore."

Lakeport, Madison co. A section from the base to the top of the Clinton formation is afforded by the test hole drilled at Lakeport, on the south shore of Oneida lake, about 6 miles from the eastern end. The hole was started in the basal Lockport, a dolomitic limestone, which was underlain by 22 feet of Rochester shale.

STRATA	FEET
Limestone, with much shale and 6 inches of iron ore at 66 feet depth	17
Shale, with limey bands	227
Ore, fossil, alternating with limestone and shale	2½
Shale, with thin limestone	45
Ore, oolitic	1
Sandstone, shaly at top	2

The thickness of the strata aggregates 295 feet. This is about the maximum for the Clinton in New York State. The main element of the formation, as will be observed, consists of the upper shale, above the ore horizon, which reaches a much greater thickness than in any other portion of the belt. The presence of this great bed of shale affords an explanation for the depression occupied by Oneida

[1] Geol. Soc. Am. Bul. 1892. 4: 102.
[2] Geol. Soc. Am. Bul. 1892. 4: 97.

lake which lies mainly within its area of outcrop, extending east and west along the strike. The more resistent strata of the Oneida and Medina formations border the lake on the north and the contours rise rather rapidly from the shore line, while to the south there is a level stretch several miles wide underlain by the upper Niagaran and Salina beds before the first line of ridges is reached. The basin is the result, thus, of differential weathering and erosion, performed in large part perhaps during glacial times.

Verona, Oneida co. The Clinton strata are well exposed in Verona township, northeast of the city of Oneida. They occupy a strip from 4 to 5 miles wide that is clearly defined by the outcrop of the Oneida conglomerate on the north and the Lockport limestone on the south. The conglomerate occurs in close proximity to the lower Clinton shale. The latter, as shown by the section obtained in the test well at Verona Station, has a thickness of over 35 feet, considerably more than in the sections to the west. It increases still more eastward until at Clinton the thickness is nearly 100 feet.

There is much interest attached to the ore occurrence in this vicinity, since the character of the hematites appears to be quite different from that of the ores exposed around Clinton and in the town of Westmoreland where the next outcrops to the east are found. The main bed is a fossil ore and occupies the same relative horizon in the formation as the Clinton oolitic bed. The presence of a second seam, from 25 to 30 feet above this bed, is evidenced by the excavations made in the village of Verona. This seam consists of lean, limey fossil ore containing crinoid fragments and large-sized brachipods. There appears to be a third ore horizon, still higher up, represented by the seam that comes to the surface on the Donnelly farm, 5 miles northwest of Oneida and is possibly identical with the ore mentioned by Vanuxem[1] as occurring at Joscelin's Corners, between the hamlets of Lakeport and Oneida Lake. Its horizon is shown by the thin band found at 66 feet in the Lakeport hole.

Clinton, Oneida co. Though this is the type locality for the Clinton formation, the stratigraphic relations here are still somewhat indefinite. No sharp line of demarcation can be found between the Clinton and the Oneida-Medina formations below, and the upper limits are equally difficult to determine. A solution of the problem must await further comparison of the fauna with that afforded by the exposures to the west. From a paleontological standpoint, some

[1] Geol. N. Y. 3d Dist. 1842. p. 89.

evidence exists that a part of the upper beds hitherto assigned to the formation may belong to the age of the Rochester shale.

The section at this locality, as given by C. H. Smyth jr,[1] is as follows:

STRATA	FEET
Calcareous sandstone, thin shale layers	50+
Ore, red flux	6
Calcareous sandstone	6
Blue shale, thin sandstone layers	15
Ore, oolitic	2
Shale	2
Ore, oolitic	1
Blue shale, thin sandstone layers	100±

It is manifest that the formation here assumes a lithic character that is quite different from the succession heretofore described. Above the upper calcareous sandstone there is a gap of undetermined extent before the Lockport is reached. In the sections to the east, occurs a heavy gray sandstone, 70 feet thick as a maximum, forming what has been considered the uppermost member of the Clinton.

Herkimer county. The eastern end of the Clinton belt crosses southern Herkimer county into Otsego county. The relations in this region are not well known, and it is impossible as yet to fix accurately the bounds of the formation. The following sections from Hall[2] show the details of the succession so far as established.

Near the boundary of the towns of German Flats and Warren the strata are exposed along Flat creek. This locality is referred to by Hall as Tisdale's mill.

STRATA	FEET
Gray sandstone, upper termination of formation	60
Shale	2
Sandstone and shale with iron ore	20
Green shale with arenaceous matter, pebbles etc	25
Coarse sandstone, with much shaly matter	10–15
Green shale with fucoids	?

The Oneida conglomerate below was not observed by Hall, but its presence both here and in the vicinity has been determined by one of the writers (C. A. H.). The ore can not be seen in place, though it occurs as float in the creek bed. It is of oolitic character.

[1] In Kemp's Ore Deposits of the United States. 1895. p. 104.
[2] Palaeontology of New York. 1852. 2:15 *et seq.*

Near Deck, in the town of Little Falls, is the section described by Hall as found at Wick's store in the town of Stark.

STRATA	FEET
Sandstone and conglomerate, uppermost Clinton member	?
Sandstone, thin bedded, with fucoids, alternating with shale	?
Red sandstone, cross-bedded	?
White sandstone, with pebbles and green shale	?
Conglomerate (Oneida)	?

Montgomery county. The following section is reported by Hall as found at Vanhornesville in the town of Stark.

STRATA	FEET
Red sandstone, coarsely laminated, friable, containing much iron ore but no distinct beds	?
Green shale, fossiliferous	?
Red sandstone, cross-bedded	?
Gray sandstone and conglomerate with thin layers of green shale	?
Conglomerate (Oneida)	?

The locality in the town of Canajoharie mentioned by Hall has not been certainly identified. The highest formation occurring within the present limits of the township is the Hudson river. The section may be the one on Canajoharie creek, in Otsego county, or more likely the section north of Cherry Valley, near Salt Springville, which is approximately at the eastern termination of the Clinton formation. The section is as follows:

STRATA	FEET
Coarse sandstone, with much iron ore	?
Shale	?
Grayish sandstone, conglomeritic below, darker and laminated above	?
Conglomerate (Oneida)	?

The total thickness is estimated at less than 50 feet. The presence of the Clinton beds can not be ascertained from the exposures at Cherry Valley, and they may have thinned out entirely. At Sharon Springs, 7 miles farther east, the Salina rests directly upon the Hudson River shales, the whole of the Niagaran and Oswegan groups having disappeared.

EXPLORATION OF THE CLINTON FORMATION

Little or no effort has been made, hitherto, toward the exploration of the Clinton ores outside the limited sections where they are mined. In the stretch from the Oneida-Herkimer county line to the western border of Wayne county, a distance of 120 miles measured along the outcrop, only a small portion is revealed sufficiently by exposure or mining excavations to permit of investigations from the surface. Previous knowledge of this area has been based largely on data secured from the eastern and western extremities; the included interval of nearly 100 miles in which the beds are, for the most part, mantled by glacial drift, has attracted little attention from mining enterprises and its possibilities for ore production remained practically unknown. The mine developments so far made, moreover, are superficial, giving no safe basis for inference as to the changes that may take place in depth.

A recommendation for an appropriation to be used in conducting exploratory operations within the Clinton belt was submitted to the State Legislature last year through the Education Department. The sum of $5000 (one half the amount requested) was allotted for the purpose. With this assistance, it has been possible to put down a number of test holes along the concealed portion of the outcrop and for the first time to establish the position, extent and character of the ore in a general way over many parts of the area. While the original plans called for the drilling of holes at intervals of 4 or 5 miles, east and west, with occasional deeper borings as might be required to explore the continuations of the beds on the dip, they had to be modified materially to meet the limitation in the allowed appropriation. Instead of attempting to carry out the work on a detailed comprehensive scale, which could only have been brought to partial completion under the circumstances, it was considered advisable to cover as much of the territory as possible by placing the holes far apart and restricting them to a single series near the outcrop.

The conditions throughout the Clinton belt, fortunately, are such that they both facilitate exploratory operations with the drill and permit reliable deductions from the obtained data. The ore seams maintain a fairly constant horizon in the series so that there need be little error in estimating the depth at which they will be encountered in most places. This regularity of position is attended by an equal uniformity in their areal development, as might be expected from bedded deposits. The character or thickness of any seam is subject to local variations, of course, but permanent changes take place

very gradually as a rule. The volume of ore contained by a given area can thus be ascertained with reasonable accuracy from observations taken at wide intervals, even of several miles under favorable circumstances.

The present exploratory work was performed entirely with a diamond core drill. By this means a core, 1 inch in diameter, representing a section of the rocks and ore penetrated was secured. The cost of drilling has been somewhat greater than if the holes had been put down without attempting to obtain a core, but the increased expense may be considered to be counterbalanced by greater accuracy and detail in the results.[1]

With the meager information to be had from outcrops, the drill cores have served also to clear up many doubtful points regarding Clinton stratigraphy. The succession of rocks has now been established with satisfactory completeness throughout the belt.

The holes to the number of 8 in all were put down between Wallington, Wayne co., and Verona Station, Oneida co. The average interval between successive holes may be stated at about 10 miles. Most of the sites were selected with a view to striking the ore at depths between 100 and 200 feet, a convenient depth for the drill as well as one that permits estimation of a large volume of the deposits. Under normal conditions of dip and surface topography the holes would be from 1 to 3 miles from the outcrop, and their results can thus be accepted with a degree of safety as an average for about twice that width across the dip.

The detailed sections for each drill hole are shown in the tabulations that follow. From their consideration, together with the facts hitherto ascertained, it has been possible to prepare a general survey of the ore distribution throughout the belt.

Wallington, Wayne co. The site of the drill hole is on the farm of Isaac Du Bois about ½ mile west of the trolley station at Wallington, on the west side of Salmon creek and approximately 5 rods north of the highway leading from Wallington to Sodus village. The locality lies 1½ miles north of the outcropping edge of the Lockport dolomite, which is shown in the vicinity of Sodus Center, and 2⅝ miles directly south of the site of the old Sodus iron furnace on Salmon creek, near which the Clinton strata with a thin seam of ore are exposed.

[1] It may be mentioned that the diamond drill proved to be well adapted for the work. Owing to the frequent alternations of hard and soft strata characteristic of the formation, it was thought some difficulty might be encountered in removing a core; but in every case a nearly complete section was obtained. The occasional loss of a part of the core due to grinding of the harder material in the "core barrel" entailed no serious discrepancies in measurements, since a constant check was maintained by observations of the lengths of the drill rods in use and the character of the rock material washed up from below.

SECTION AT WALLINGTON

Strata	From		To		Character
	Feet	Inches	Feet	Inches	
Soil	0	0	2	6	
Shale	2	6	70	0	Light gray above, becoming darker and more fossiliferous below. Represents basal Rochester.
Limestone	70	0	80	0	Light colored, layers 2 to 16 inches separated by thin shales, 1 to 6 inches. Upper Clinton limestone.
Shale	80	0	88	0	In appearance this shale is similar to the basal Rochester. It is fully as dark and its numerous fossils are evenly distributed through the mass, giving it a variegated appearance.
Shale	88	0	100	0	Similar to above, but with fewer fossils and of a lighter shade.
Shale	100	0	115	8	These dark layers include the graptolite beds with the characteristic form M. clintonensis.
Limestone	115	8	130	6	The limestone contains layers of shale 1 to 3 inches thick. Pentamerus is the characteristic fossil of the limestone.
Shale	130	6	133	6	Fossiliferous dark and olive-gray shale with included bands of limestone. Transitional from the limestone above. The division is at point where shale predominates over the limestone.
Shale	133	6	182	0	A uniform purple shale; contains bands of pearly limestone made up of the fossil Anoplotheca hemispherica.
Shale	182	0	184	0	The purple shale above changes rather abruptly to this olive-gray shale which passes gradually into the limestone below.
Limestone	184	0	197	6	Characterized by the fossil Pentamerus. The limestone is uniform above. Near the middle is found some flinty material giving the rock a brecciated appearance. Layers of shale in lower part. First trace of ore at 195 feet.
Ore	197	6	198	6	Impure fossil ore.
Limestone	198	6	199	4	Includes some shale.
Ore	199	4	200	0	Fossil ore.
Shale	200	0	205	0	Soft green calcareous shale. The upper 2½ inches is brecciated, arenaceous limestone containing black shale pebbles.
Shale	205	0	207	0	Soft mottled shale of the Medina formation.

The section shows two beds of fossil ore, separated by 10 inches of limestone. The horizon is the same as the main bed at Wolcott and the bed at Ontario Center. While the ore maintains an average thickness for this region, it is hardly of mineable grade, containing as it does seams of unreplaced limestone, besides the heavy parting. A light flow of gas was encountered at 45 feet, in the Rochester shale.

Wolcott, Wayne co. The drill hole was put down on the east bank of Wolcott creek, within the village limits, about 300 yards below the falls. A boring for gas was made some years ago on the other side of the creek and about 20 rods farther north. The hole was started at approximately the same horizon in the Rochester shale as the one at Wallington. The upper ore bed outcrops 1¼ miles directly north, along Wolcott creek, near the site of the old Wolcott furnace.

SECTION AT WOLCOTT

Strata	From Feet	From Inches	To Feet	To Inches	Character
Soil	0	0	5	6	
Shale	5	6	44	0	Dark fossiliferous shales, somewhat lighter near the top where are found some bands of light colored limestone. Rochester shale.
Limestone	44	0	57	0	Considerably mixed with fossiliferous shale. Purest at top and bottom. Cavities in limestone lined with crystals.
Shale	57	0	101	4	Dark shales with graptolites. Includes some lighter colored shale.
Ore	101	4	102	4	Fossil ore.
Limestone	102	4	124	0	Alternating series of limestone and shale. Pentamerus characteristic fossil of the limestone.
Shale	124	0	127	0	Olive-gray shale free from limestone bands.
Shale	127	0	182	0	Purple shale with a number of thin bands of pearly limestone with fossil Anoplotheca hemispherica.
Shale	182	0	186	0	Olive-gray shale. Two inch band of ore at 186.
Limestone and shale	186	0	198	9½	The upper 16 inches is a fossiliferous limestone. Below is a shale with bands of limestone. The lower 3 feet is an impure limestone.
Ore	198	9½	199	0	Fossil ore.
Limestone	199	0	199	4	Impure limestone.
Ore	199	4	200	11	Fossil ore.
Shale	200	11	203	0	Calcareous shale with some very thin seams of limestone. At top is a 2 inch layer with black shale pebbles.

The upper 1 foot seam is the one that was worked in the early days near the furnace on Wolcott creek. The lower beds do not appear in the vicinity; the line of their outcrop must lie between 2 and 3 miles north of Wolcott. They are undoubtedly a continuation of the seam that is exposed in the excavations at Sterling Station and again shown in the hole near Red Creek, between that place and Wolcott. There is thus an area fully 10 miles long, east and west, which is underlain by an unbroken seam from 18 to 36 inches thick. As the holes are nearly 3 miles back from the outcrop, the continuity of the ore on the dip for any distance within easy reach of mining operations may be regarded as certain. The dip of the beds in this section is less than 50 feet to the mile.

The accompanying analyses show the composition of the beds at Wolcott. No. 1, by James Brakes, relates to the upper 1 foot seam and no. 2, by E. Touceda, to the main seam.

	1	2
Fe_2O_3	44.71	44.38
SiO_2	23.98	8.56
TiO_2	.225	....
Al_2O_3	7.26	5.04
MnO	.....	tr.
CaO	9.15	13.71
MgO	2.92	7.37
SO_3	.987	.072
P_2O_5	.549	1.58
CO_2	9.6	18.8
H_2O	.26	undet.
	99.641	99.512
Iron	31.3	31.07
Phosphorus	.24	.69

Red Creek, Cayuga co. This test was made on the farm of M. H. Frost, 2 miles northeast of Red Creek, Wayne co., and 3 miles southwest of Sterling Station. The exact location is just north of the highway, beside the small stream that crosses the road east of the house.

SECTION AT RED CREEK

Strata	From Feet	From Inches	To Feet	To Inches	Character
Glacial drift	0	0	9	0	
Shale	9	0	42	0	Shale varies from light to dark, with calcareous layers. Large fossils at 23 feet.
Shale	42	0	50	0	Quite uniform, light calcareous shale.
Shale	50	0	86	0	Light colored shale above, with dark graptolite layers below. The basal portion includes some thin bands of limestone. At 69 feet is a 3 inch layer with black pebbles.
Limestone	86	0	103	0	This division consists of alternating layers of limestone and shales.
Shale	103	0	169	4	Purple shale. The upper 10 feet is olive-gray, grading into the purple below. The shale contains many limestone bands up to 6 inches thick.
Ore	169	4	169	8	Fossil ore.
Limestone	169	8	171	8	Gray fossil limestone.
Shale	171	8	176	8	Shale shows a purple tinge. Contains some fossil limestone bands.
Limestone	176	8	178	0	Gray fossil limestone.
Ore	178	0	180	6	Fossil ore—2 inches of shaly material near the middle.
Shale	180	6	184	0	This is a dark shale with many small "fucoidal" markings, giving it a mottled appearance. Only a few thin bands of limestone present. The upper 3 inches is a breccia.

The test hole shows that the bed exposed at Sterling Station extends thus far in undiminished thickness. There is no noticeable change also in the character of the ore. A sample of the drill core was analyzed by E. Touceda with the following results:

Fe_2O_3	48.7
SiO_2	5.13
Al_2O_3	4.99
MnO	.003
CaO	12.6
MgO	7.75
SO_3	.096
P_2O_5	.477
CO_2	18.35
H_2O	undet.
	98.096

Iron	34.09
Phosphorus	.208

Martville, Cayuga co. The site of this drill hole is on the west bank of Sterling creek about 15 rods below the bridge at Martville, on the property of Dr John Chapman. The locality is 3 miles southeast of Sterling Station and 5 miles northeast of Red Creek.

SECTION AT MARTVILLE

Strata	From Feet	From Inches	To Feet	To Inches	Character
Drift and broken shale	0	0	18	0	
Shale	18	0	83	0	With the exception of a few feet at base, this shale is purple in color. It includes a number of pearly limestone bands, between 33 and 57 feet. A few other light crystalline limestone bands occur at 45 and 54 feet. In thickness the bands of limestone vary from a fraction of an inch up to 6 inches.
Shale and ore	83	0	89	0	One inch of lean ore is followed by 1 foot of shale and limestone. Another inch of lean ore at 84′ 5″, followed below by dark shale with limestone bands.
Limestone	89	0	93	0	Fossiliferous limestone with bands of shale. Below this limestone is the horizon for the main ore bed as encountered in the drillings farther west.
Sandstone and shale	93	0	98	0	Upper few inches brecciated, followed below by greenish shale and sandstone. Below this is a very hard white sandstone, followed by a foot of mottled sandstone. Medina horizon.

This section seems to establish that the ore body which stretches across Wayne county and as far east as Sterling Station, Cayuga co., terminates practically near the latter locality. The excavations made by the Fair Haven Iron Co., at Sterling Station, give some indications of a wedging out of the ore toward the east, though from the evidence here it does not follow that this is anything more than a local condition. The ore bodies are everywhere subject to moderate variations in thickness, but the pinches are usually succeeded in turn by bulges that maintain the average. There is no other

locality, so far as has been determined, where a thick bed diminishes in such short distance to a thin seam.

South Granby, Oswego co. The site of this drill hole is on the farm of Alonzo Lutentelly, 1 mile southwest of South Granby, and 1½ miles north of Little Utica, on the west side of the highway leading north from the latter place where it is crossed by a small stream.

SECTION AT SOUTH GRANBY

Strata	From		To		Character
	Feet	Inches	Feet	Inches	
Sand and gravel.	0	0	22	0	
Shale	22	0	39	0	Dark shale, full of fossils—Rochester horizon.
Limestone	39	0	40	6	Impure limestone with fossils.
Shale	40	6	89	0	Shale with a little limestone. At 76 feet is a 1 inch band showing dark pebbles with pyrite.
Shale	89	0	102	0	Shale quite free from limestone bands. At 101 feet there is a thin seam of ore and the shale contains for 4 inches numerous crystals of pyrite. At 102 feet there are 4 inches of limestone with large brachiopods.
Shale	102	0	135	2	Shale with some very dark bands towards the base.
Limestone	135	2	136	1	Light colored limestone with fossils. Near the middle the fossils are replaced by iron ore.
Shale	136	1	138	9	Calcareous shale.
Ore	138	9	139	0	This band of ore is richest below, grading into a highly colored shale above with thin seams of ore.
Shale	139	0	140	0	Shale with band of limestone at the middle.
Limestone	140	0	140	8	Coarse, light colored limestone.
Limestone	140	8	145	3	Coarse, fossil limestone with some shale.
Limestone	145	3	145	6	Lean fossil ore.
Limestone and shale	145	6	154	0	Gray compact limestone and alternations of lighter colored limestone and shale.
Shale	154	0	223	1	Gray shale with bands of limestone. The limestone bands include a number of the pearly layers; also some fine compact bands. None of the bands of limestone are over 6 inches thick.
Ore	223	1	223	9	Oolitic ore with some fossils at base.
Shale	223	9	228	0	Mottled shale with bands of limestone. One inch of shale with pebbles found 2 feet below the ore. Mottled appearance of shale due to organic remains.

The hole is about midway between Sterling Station and the west end of Oneida lake, an interval that seems to be barren of workable deposits. More tests are needed, however, to demonstrate their entire absence, since the distance to the Martville locality is 10 miles and to Brewerton, the next drill site to the east, about 12 miles.

Brewerton, Onondaga co. The drill was set up on the south shore of Oneida river, within the village, about 75 yards west of the bridge. This point is very near the Oswego-Onondaga county border and the south line of the route followed by the new Barge canal.

SECTION AT BREWERTON

Strata	From		To		Character
	Feet	Inches	Feet	Inches	
Clay	0	0	14	0	
Shale	14	0	56	4	Olive-gray shale with many dark bands in the lower part and with few thin bands of limestone. At 19 feet there is a 4 inch band with black pebbles.
Ore	56	4	56	6	Fossil ore, inclosed in shale.
Shale	56	6	79	6	Shale with limestone bands 3 to 4 inches thick found at quite regular intervals. The limestone contains cavities lined with crystals. Traces of ore, as threadlike veinlets, are found in the limestone.
Shale	79	6	138	4	Shale with thin bands of limestone that probably represent the pearly layers. Trace of ore at 133 feet.
Ore	138	4	139	8	Oolitic ore.
Sandstone and shale	139	8	145	0	The layers below the ore are quite variable. The 2 inches immediately below the ore is shale; then follows a sandstone or conglomerate, becoming coarser toward the bottom.

This section is similar to the one at South Granby in showing two ore seams separated by many feet of rock. The absence of limestone is a striking feature and serves to connect this section with the eastern development of the Clinton, as exemplified in Oneida and Madison counties, rather than the western belt. This is further indicated by the oolitic structure of the lower ore seam.

The 16-inch bed is solid ore of uniform character. It will repay

further exploration. The site of the hole was chosen purely for convenience, and the chances are very remote that the thickest portion of the bed was encountered by the single test. The discovery is thus of considerable potential importance. The ore was sampled by taking a longitudinal section of the core and an analysis by E. Touceda gave the following percentages.

Fe_2O_3	48.71
SiO_2	9.69
TiO_2	.244
Al_2O_3	3.21
MnO	tr.
CaO	13.8
MgO	4.23
SO_3	.141
P_2O_5	2.38
CO_2	15.45
H_2O (combined)	2.33
	100.185
Iron	34.1
Phosphorus	1.038

Lakeport, Madison co. The site of this drill hole is 1½ miles northeast of Lakeport on the farm of Robert Cowen. The drill was placed near the spring south of the highway, a little more than ¼ mile distant from the shore of Oneida lake.

SECTION AT LAKEPORT

Strata	From Feet	From Inches	To Feet	To Inches	Character
Drift	0	0	7	0	
Limestone	7	0	21	0	This is a dolomitic limestone representing the basal Lockport.
Shale	21	0	50	0	Fossil shale—Rochester horizon.
Limestone	50	0	67	0	Limestone with considerable shale. Six inches of lean fossil ore at 66. Other traces of ore in the limestone.
Shale	67	0	129	0	Alternating layers of dark, light and mottled shales with considerable amount of light fine grained calcareous sandstone.

SECTION AT LAKEPORT (*continued*)

Strata	From Feet	From Inches	To Feet	To Inches	Character
Shale	129	0	135	0	This is a shaly limestone with bands of shale. The limestone is fossiliferous and contains several bands of very lean ore, with many crinoid stems.
Shale	135	0	152	0	Shale with abundant fossils.
Shale	152	0	171	0	Olive-gray shale with fossils—a few thin bands of limestone.
Shale	171	0	276	0	Light and dark shale, with few bands of limestone. At 171 feet there is a 4 inch band with black pebbles.
Shale	276	0	294	6	Shale with limestone bands, 3 to 4 inches thick. Some of the bands show faint traces of ore.
Ore	294	6	295	1	Lean fossil ore.
Shale	295	1	295	10½	Gray shale.
Ore	295	10½	296	3	Fossil ore.
Limestone	296	3	296	11	Whitish limestone with 1½ inch of shale at base.
Ore	296	11	297	0	Fossil ore.
Shale	297	0	328	0	Light and dark shale with thin bands of limestone. Trace of ore at 328 feet.
Shale	328	0	335	0	Shales with bands of limestone. Both contain fossils.
Shale	335	0	342	3	Soft, very dark shale with a few bands of a lighter color.
Ore	342	3	342	10	Oolitic ore, with fragments of bryozoans.
Shale	342	10	342	11	This is a dark shale dividing the ore.
Ore	342	11	343	3	Coarse grained ore, associated with calcareous sandstone.
Sandstone	343	3	345	10	The upper 4 inches is a band of shale with 2 inches at middle of a conglomeratic nature. The basal 6 inches is a white sandstone. The remaining portion contains thin layers of mottled, dark, sandy shale. Some of the sandstone has a reddish tinge showing faint traces of ore.

This hole was intended to test the long stretch between Brewerton and Verona throughout which the Clinton formation is mostly concealed. The results indicate some similarity of conditions in regard to ore deposition with the section at Brewerton and also with that at Clinton, but the oolitic bed is much

thinner and the fossil ore is broken by intercalations of limestone and shale. The latter rock reaches its extreme thickness here, the hole showing 227 feet without practical interruption from the base of the limestone which is taken as the uppermost Clinton to the first seam of ore.

Verona, Oneida co. The site of this drill hole is 100 yards west of Verona Station, on the Davis farm, just south of the highway where it is crossed by the creek. It is 2½ miles southwest from the nearest outcrop of the Oneida conglomerate. The Cagwin opening for ore is 1 mile and the Klein opening 1½ miles from this locality.

SECTION AT VERONA STATION

Strata	From		To		Character
	Feet	Inches	Feet	Inches	
Sand and clay...	0	0	18	0	
Shale.....	18	0	37	2	This is a light colored shale with only a few thin bands of limestone.
Ore.....	37	2	38	2	Fossil ore.
Shale.....	38	2	74	0	Shale quite uniform as regards texture. A few thin bands of limestone, up to 2 inches thick.
Sandstone and shale.....	74	0	84	4	These layers are quite variable. Some are made up of light sand in a dark shale matrix. The upper 2 feet is a fine grained calcareous sandstone. A few of the layers contain pebbles.

The object of putting down a hole at this locality, which is only a mile or so distant from old mine workings on the Clinton, was to test for a possible oolitic bed below the fossil ore which alone has been known. The presence of a lower ore horizon would appear probable from comparison of the two sections at Clinton and at Brewerton, east and west respectively of the present locality. In both sections two beds are shown, the lower being oolitic. The fossil nature of the Verona ore indicates relationship with the upper or red flux bed found to the east. The oolitic bed, so far as it can be identified, thus disappears in the interval.

The character of the fossil ore is shown by the following analysis made by E. Touceda on a sample of the ore.

Fe_2O_3	40.92
SiO_2	7.06
TiO_2	tr.
Al_2O_3	11.13
MnO	tr.
CaO	14.68
MgO	3.84
SO_3	.025
P_2O_5	1.02
CO_2	16.3
H_2O (combined)	4.88
	99.855
Iron	28.64
Phosphorus	.445

ORE DISTRIBUTION AND RESOURCES

Over most of the area occupied by the Clinton, the hematite beds contribute an essential feature to the sedimentary succession. They are, indeed, next to the shales, the most persistent element in the formation as represented in the State, having a wider development than either the limestones or sandstones.

Their eastern and western limits are somewhat indefinite, due to the long intervals between exposures; it is a question, also, not of an abrupt termination, but of a gradual thinning to disappearance with the progressive diminution of the formation itself.

At Rochester, the extreme westerly point where the ore is known to be represented, there is a single bed of fossil hematite 14 inches thick. This is very likely a continuation of the bed which stretches across Wayne county and is mined at Ontario Center, 15 miles northeast of Rochester. At any rate the ore shows so moderate a decrease within the interval that its continuity for a considerable distance farther west seems probable. Beyond Rochester there are no good exposures until the Niagara gorge is reached where the ore fails entirely and the whole section of the Clinton is reduced to 40 feet or less.

On the eastern end the hematites can be traced as far as the Oneida-Herkimer county border without any noticeable changes of character. After passing that line their thickness falls off quite rapidly. At the outcrop west of Frankfort hill, in the town of Frankfort, Herkimer co., the oolitic bed measures only 10 inches, which is about one third the amount represented at Clinton, 9 miles west. The red flux bed on the other hand is still fairly well maintained as regards thickness, showing about 40 inches. Following the strike to the southeast across southern Herkimer county, the beds appear to give out within a short distance, for they can not be identified in the outcrops, or else they shade off into a ferruginous sandstone that is much different from the normal ore varieties. In the exposures along the hills south of the Mohawk river, between Frankfort and Herkimer, neither the oolitic nor the red flux bed can be seen, but there are 10 feet or more of deep red sandstone heavily charged with hematite. The latter functions as cement to the quartz grains, but does not encrust them. The iron content of the sandstone may be placed at about 10%. The entire Clinton disappears, so far as surface indications are concerned, near the eastern border of Herkimer county.

The ore seams thus attain their fullest development in respect to thickness within the stretch from eastern Oneida to western Wayne county. Beyond these limits they have little economic importance for the present, at least, and their exploration is not of immediate concern.

The information gained from the test drilling, described elsewhere in this report, serves to show the distribution of the more valuable ore bodies with some precision. It has been found that the ore is mainly gathered into four areas which succeed each other along the outcrop, after longer or shorter intervals that are characterized by thin seams, much below the average, or by their almost complete disappearance. There is a possibility of one or two additional areas being present that have escaped notice by reason of the wide spacing of the holes, but they must be of minor extent compared with the others.

The area which centers about Clinton, Oneida co., has been the principal source of the ore in the past. There are two seams here, an upper of fossil character called the red flux bed and a lower oolitic bed that is sometimes split into two portions by a layer of barren rock. The fossil ore is too lean to be used

in the furnace. It attains the notable thickness of 6 feet. The oolitic bed extends through the towns of New Hartford, Kirkland and Westmoreland and is of mineable grade over most of the territory in which it is exposed. It ranges from 20 to 36 inches, with an iron average of 40% or a little more in places. A subordinate area, perhaps connected with this, is found in the town of Verona, where some ore was obtained for the early furnaces. The workings are 7 miles distant from the proximate outcrops in the town of Westmoreland. The bed measures from 12 to 20 inches and is of fossil nature. The oolitic bed is absent from this section.

The test hole at Lakeport, the only one put down in the stretch of 30 miles from Verona Station to the west end of Oneida lake, was unfavorable for the presence of any considerable volume of ore in this vicinity. At Brewerton, 15 miles from Lakeport, a 16-inch bed of oolitic ore was found. This is a new discovery and is nowhere exposed at the surface. That it underlies a considerable area seems quite certain, and it doubtless attains a greater thickness than indicated by the test. Further exploration is needed to ascertain its full value.

After an interval in which the formation crosses the southwestern corner of Oswego county without the appearance of any considerable ore bodies, the third area is encountered in northern Cayuga county, beginning near Sterling Station. The excavations along the outcrop here show from 30 to 36 inches of fossil ore, while within 1 mile to the south the bed is reported to increase to 40 inches. The bed has been proved as far west as Wolcott where the drill encountered 21 inches while an overlying 12-inch seam comes in at this place. The drill hole put down at Red Creek midway between Wolcott and Sterling Station showed the main bed to be 30 inches thick. The two drill tests have demonstrated the extent of the ore to be much greater than hitherto known. All that has been done previously in the way of exploration consisted of shallow open cuts and drill holes on the eastern end, which afforded no satisfactory evidence of the character and volume of the ore to be found to the south and west. The average iron content of the main bed may be placed at about 35% to 38%.

The continuation of the ore bed immediately west from Wolcott has not been prospected. It may be assumed, however, that the main seam thins in this direction, or is broken up by

intercalations of limestone, which is in accordance with the results found at Wallington, 10 miles from Wolcott. At about the same distance beyond Wallington, in the town of Ontario, Wayne co., is an area that contains a bed of fossil ore from 18 to 30 inches thick. This seam has been worked for a distance of 5 or 6 miles east and west and explored by the mining companies several miles farther along the outcrop. It diminishes very gradually westward so that at Rochester it is still 14 inches thick. The ore from the surface workings in the town of Ontario averages 40% or slightly more in iron.

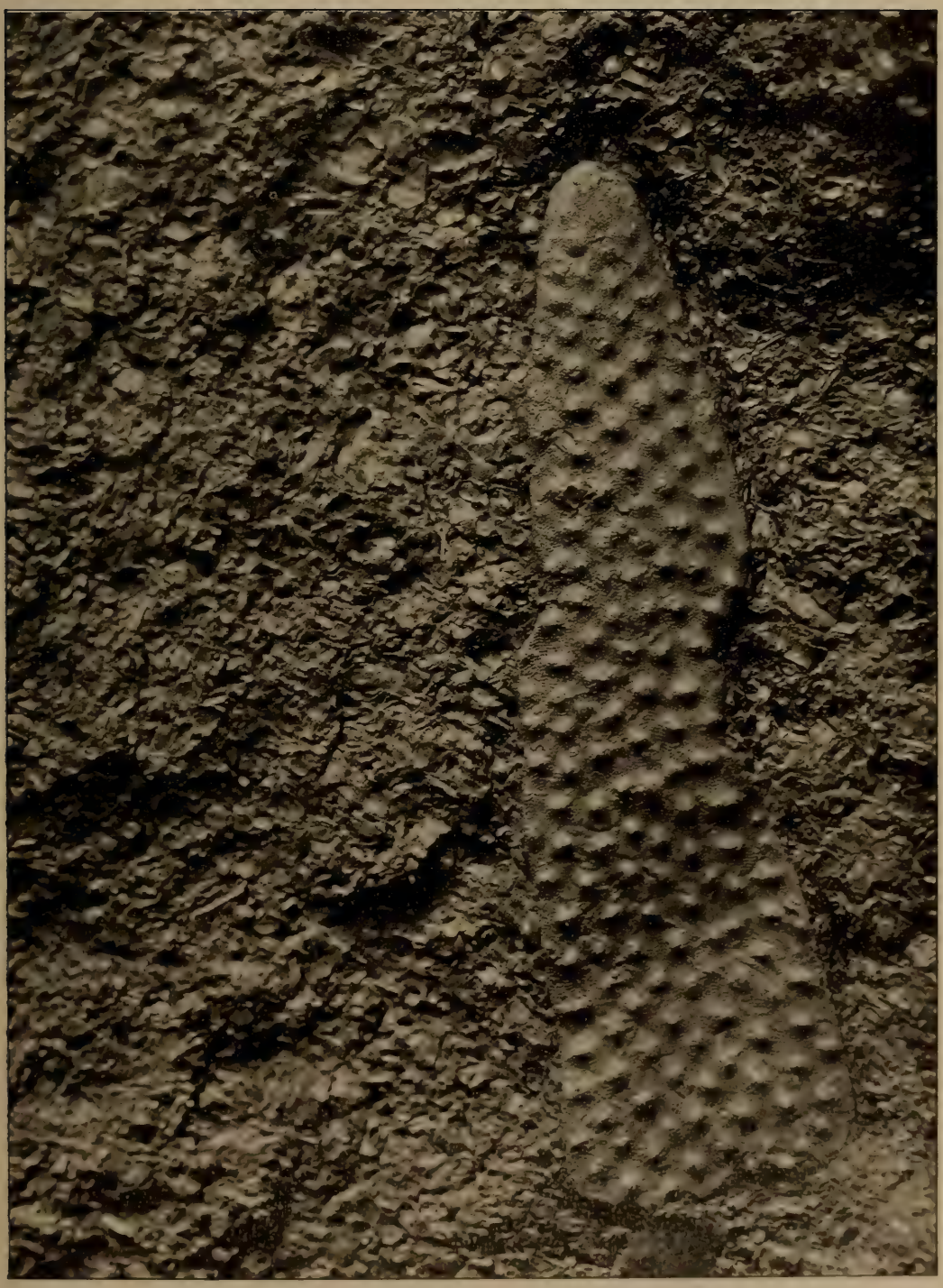
The above outline of the distribution of the hematites is necessarily tentative; it is an effort merely to interpret the data thus far at hand. There are many gaps to be filled in, and much additional information is required concerning the sections even that are best known before an ultimate survey of the conditions is possible. The available evidences suffice, however, to indicate in some measure the possibilities of the Clinton formation as a future source of iron ore.

The volume of ore which is subject to estimate within the areas mentioned is such that it must be considered one of the more important reserves in the present fields of iron mining. A great proportion, of course, will not be subject to profitable extraction for many years to come. But if limitations be put upon the estimate, so as to bring it into relation more or less close with the existing status of the mining industry, the total will still be large.

Thus, to provide a reasonable basis of calculation, we may exclude all ore that is below 18 inches thick or more than 500 feet from the surface, also leaving out of account the beds that are below the average in iron content. Under these restrictions the quantity available in the three principal areas may be placed at approximately 600,000,000 tons.

The larger part of the ore resources available for underground mining is represented by the western areas of Cayuga and Wayne counties. The inclination of the beds in this section is usually less than 50 feet to the mile, while the surface rises very gradually southward; consequently mining could be extended for a long distance (from 5 to 6 miles) on the dip before the depth of the workings would reach 500 feet. That the ore may be expected to hold out for such a distance has been practically demonstrated by the borings at Wolcott and Red Creek which penetrated the beds at points about 3 miles back from the line of outcrop. Its continuity

Plate 3



Fossil ore from Ontario, Wayne co. Slightly enlarged. The large fossil is a bryozoan, Phaenopora constellata.

is also to be inferred from the persistence of the beds along the strike.

In the Oneida county area, on the other hand, though there is a stretch of fully 10 miles east and west in which the beds exceed the minimum thickness stated, the conditions for mining on the dip are generally less favorable. The average width of the area lying within 500 feet from the surface may be placed at 2 miles. The indicated dip is here about 150 feet to the mile.

With large scale operations the cost of ore extraction down to a depth of 500 feet should not be much, if any, over $2 a ton. It would appear that this limit is easily within range of economic mining for the near future, though with the large resources lying near the surface there will be no incentive to extend operations to such a depth for many years to come.

THE ORES

Mineralogy and structural features

The Clinton ores belong to the red, earthy variety of hematite. In some specimens a little specular hematite is present, due to resolution and crystallization after the beds were laid down; siderite or iron carbonate also occurs locally in small amount distributed in fine particles through the mass. The bulk of the ore, however, consists invariably of amorphous hematite, red or brownish red in color and streak. The specific gravity of the ore ranges between the limits of 3.5 and 3.8. For purposes of calculation it may be assumed that a cubic foot weighs 225 pounds.

Compared with the hematites occurring in other surroundings, the Clinton ores may be distinguished by certain structural peculiarities, descriptive of which are the terms oolitic, lenticular, fossil etc., that are applied to them in the various mining districts. These structures are related to the methods of origin and are singularly persistent.

An examination of representative specimens from the New York beds brings out the fact that the hematite forms two kinds of aggregates, each giving a distinctive character to the ores in which it predominates. The one consists of spherical or somewhat flattened grains, quite uniform as to size and having the appearance of being solid hematite. When separated from the matrix and broken, or when observed in thin section, it is usually seen that the grains have a nucleus, generally a minute quartz kernel, about which the

hematite is arranged in concentric layers. In each ore particle may be recognized often a number of such layers. Their deposition has taken place at successive intervals while the grains were moved about and in complete contact with the iron-bearing solutions. The formation of oolitic limestone illustrates the general conditions that must have prevailed during the deposition of the ore. The second type of structure found in the Clinton ores is distinguished by the occurrence of the hematite with an organic form, due to its replacement of some calcareous fossil such as a bryozoan, crinoid or brachiopod. The fossils may be wholly replaced, but more commonly a portion of the original lime is retained in the interiors, and in some cases the change has not progressed beyond the outer surfaces, so that practically all steps between fossiliferous limestone and ore may be observed.

The two structures — fossiliferous and oolitic — are not infrequently found together, though in most samples from the New York beds one type so prevails as to lend a fairly uniform appearance to the ore. The oolitic structure is more limited in its development than the other. It characterizes the main bed in the eastern section, notably around Clinton and in the towns of New Hartford and Westmoreland, and is found farther west in the ore at Brewerton and Lakeport. The fossiliferous ore appears at Clinton in the so called flux bed, and forms the single deposit in the town of Verona, Oneida co. The ore mined at Sterling Station, as well as the entire section throughout Cayuga and Wayne counties, belongs to that type.

A curious feature of the oolitic grains, that has been brought out by C. H. Smyth jr, in his studies[1] of the Clinton ores, is the presence of amorphous silica in intimate association with the hematite. Though the silica layers are scarcely discernible in ordinary thin sections, they are easily revealed by subjecting the grains to the action of hydrochloric acid. When the hematite has thus been removed in solution, there remains a perfect cast of the original oolite preserved by the gelatinous, transparent silica. Apparently, the deposition of the silica took place at the same time and from the same solution as the iron.

The individual spherules are usually closely compacted and often coalescent on the borders. They are seldom more than 1 millimeter in diameter. The quartz kernels in their interiors are scarcely half that size as an extreme and range down to particles so minute that

[1] Am. Jour. Sci. 1892. 143: 488. *Also* Zeits. für prak. Geol. Aug. 1894.

Plate 4

Oolitic ore from Clinton, Oneida co.

they are observable only with the aid of the microscope. The kernels sometimes appear to be wholly absent. The quartz has the same character as that found in granitic rocks, showing liquid and gas inclusions, as well as rutile and hematite crystals. Its ultimate source, undoubtedly, is the Precambric crystallines, but the small size of the grains and their well rounded forms indicate long continued abrasion after its release from the rocks.

The texture of the fossiliferous ore varies to some extent with the locality. In the red flux bed as exposed at Clinton, the fossil fragments are coarse and the different forms can be separated and identified without difficulty. In the western part of the State, the beds show much finer texture, while the shell particles have been worn and smoothed until their organic nature is more or less concealed. The smaller fragments are often enveloped by one or more layers of hematite deposited after their replacement in the same way as with the oolitic grains.

The cementing material in both kinds of ore is usually granular calcite. There is considerable variation in the relative proportion of this mineral to the hematite. Local variations may be ascribed to solution of the calcite after the ores were laid down, but it is also to be expected that the conditions of deposition would change from time to time and from place to place. An exceptional type is represented in the eastern section in Herkimer county where there are one or more layers of what is properly a ferruginous sandstone. The fine quartz grains are not coated with hematite to any extent, but the latter fills the interstices as cement. The material is too lean to be classed as an ore.

Chemical character

The Clinton ores show considerable regularity in their chemical composition. Leaving out of consideration the locally occurring beds which are generally too lean or too thin to be workable, the ores throughout the State may be said to average about 40% in metallic iron. They seldom run above 45% or less than 35%. The higher limit is approximated by the oolitic bed in the vicinity of Clinton, where the mines of the Franklin Furnace Co. have returned an average of 44% through a period of several years. The care taken in separating the ore from the inclosing rock and in the removal of shale, sandstone or limestone partings which are often present, is an important factor in determining the yield. According to C. A. Borst, the middle portion of the Clinton oolitic bed can be mined to give

55%, while if the whole bed is taken out without sorting, the average will be about 40%. The fossil ore in the western part of the State runs from 35 or 36% to 44 or 45%.

The following analysis quoted from a paper by A. H. Chester[1] is of interest, as it represents the average from a large number of analyses of Clinton ores from Oneida county.

Fe	44.4
SiO_2	13.09
Al_2O_3	5.99
MnO	.19
CaO	5.85
MgO	2.69
S	.31
P	.53
CO_2	6.08
H_2O	1.45
O in Fe and P	19.71
	100.29

The percentages would indicate that the ores analyzed were chiefly from the oolitic bed, though no mention of localities is made in the paper.

Phosphorus and sulfur are both comparatively high in the Clinton ores. The former is seldom less than .25% and ranges up to more than 1%. Reckoned on the basis of metallic iron, the phosphorus content will average from 1 to 2%. The sulfur is more variable, being found in some ores only in traces and in others running up to .5%. It occurs always in the form of pyrite which seems to be associated rather with the shale partings than intermixed with the hematite. Between the ore and wall rock there is oftentimes a thin seam of pyrite.

Among the other important impurities of the ores are silica, alumina, lime and magnesia. Most of the silica is in the free state as quartz. Its proportion varies from a minimum of 2 or 3% up to 15%, the higher percentages being shown by oolitic ores. In the fossiliferous hematites the average may be placed at about 7 or 8%. The alumina is combined with a part of the silica to

[1] Address delivered before the Utica Mercantile Manufacturing Association, Utica, 1881.

Plate 5

Fossil fragments from the red flux bed. The ore is largely made up of such fragments of bryozoans and crinoid stems which have been partially or wholly replaced by hematite.

Plate 6

Oolitic ore, magnified so as to show quartz nuclei and concentric structure

form clay and amounts to some 2 or 3% as a rule. The lime and magnesia are due to limestone which occurs as a cementing material or as unreplaced fossil fragments. They are in largest quantity in the fossil ores where the carbonates average from 15 to 20%. The oolitic ores carry about 10 or 12% of carbonates as a rule.

Origin of the Clinton ores

The subject of the derivation of the hematites, which are so constant an accompaniment of the Clinton formation, has been repeatedly discussed in the literature relating to the geology of the different fields. There is more than scientific interest involved in the question, since the mode of origin has a bearing upon the distribution of the deposits and its determination is desirable as an aid to exploration. It has become quite evident with the progress of investigations that there is a great degree of uniformity in the character and manner of occurrence of the Clinton ores throughout their extent and that they have been formed in most, if not all, cases under similar conditions.

Of the many principles that are known to govern the accumulation of iron ores in their varied development, it is possible to eliminate all but a few as having no conceivable relation to the Clinton hematites. In fact there are but two explanations which have received the attention of geologists and need to be considered here.

According to the first view, originally advanced by James Hall in his description of the Clinton formation in western New York, the ores were formed in standing water at the same time as the inclosing beds. Hall further expresses the belief that the source of the iron is to be found in the bodies of iron oxids and pyrite contained in the old crystalline rocks. Thermal waters are considered to have been influential in the deposition of the oolitic ore and they may have hastened the decomposition of the pyrite. These conclusions were generally adopted by the early writers.

The alternative explanation, proposed by Shaler for the Clinton ores in Kentucky and favored by some geologists for the whole assemblage of Clinton ores, regards the hematite as a secondary introduction after the formation had been upraised above sea level. The ore beds are considered to be replacements of original limestones, effected by the circulation of ground waters which leached the ferruginous constituents from the overlying strata. This theory of replacement has found its principal advocates among geologists

who have worked in the southern fields where the occurrence of rich ores at the surface is at times succeeded by lean, limey ores in depth.

The evidence in support of both views has been traversed very thoroughly by C. H. Smyth jr, in a paper[1] which represents as well the results of long experience and close study of the Clinton ores both in the northern and southern districts. There can be no doubt after an impartial perusal of Professor Smyth's paper that the theory of sedimentary origin is fully substantiated for most of the occurrences. For the ores under present consideration this is the only explanation at all compatible with the conditions.

The stratigraphic features presented by the New York section of the Clinton do not lend themselves to the conception of vertical circulations of ground water such as would be required to dissolve and carry iron from the overlying strata. The ore beds everywhere lie nearly horizontal; their dip is universally toward the south at an angle no greater probably in many places than that given by the contour of the original sea bottom on which they were deposited. At no time in their subsequent history have they been steeply inclined. Moreover, they are overlain by thick shales not readily permeable to water. Underground flowage must necessarily be limited and be dependent for the most part on the cropping out of the more porous strata like the limestone and sandstone layers. Thus, it is directed rather along the bedding planes than across them. Below the ore there is also more or less shale intervening before the top of the sandstone and conglomerate basement is reached.

The existence of limestone above the ore beds has been remarked by Professor Smyth in the paper already quoted. In Cayuga and Wayne counties the fossil hematite is covered directly by limestone and there are one or more layers at varying horizons in the shale. The main ore bed in this part is generally split into two portions by a thin seam of limestone. No noticeable replacement has taken place in the overlying limestones, though this would be the first to be affected by descending iron-bearing solutions. The limestones are fine grained and compact and, where protected by shale, they show little effect of leaching in the mass or of solution along the joint planes.

The ore beds are separated by sharp division planes above and below, with no intervening zone of gradation from ore to rock. This feature is well illustrated in the process of open-cut

[1] Zeits, für prak. Geol. Aug. 1894. *See also* paper in Am. Jour. Sci. 1892. 143:487.

Partial section of the Clinton beds at Clinton, showing red flux bed in upper part

mining, by which the overlying burden is removed over a considerable area before the ore is taken out; the surface of the stratum is extremely regular and smooth, not less so than the surface of the superincumbent limestone.

In their uniformity of character the hematites possess a feature that is consistent only with a sedimentary derivation. This uniformity holds true for the beds near the surface and also with regard to the ores encountered at depths of several hundred feet from the surface. The recent exploration with the diamond drill has shown that there is no notable change of character on the dip for distances of 5 or 6 miles from the outcrop. Deep borings made some years since at Syracuse and Chittenango found the hematite below 600 feet showing it to be of normal composition.[1] The ores hold out to much greater depths than could be expected from the work of underground waters.

Enrichment by solution and redeposition of the iron has not occurred in the New York beds. Whatever variation in iron content there may be is to be regarded as original or as due to weathering on the surface. There are no bodies of soft ores at all comparable to those found in the southern districts. This may be ascribed in large measure perhaps to the effects of the glacial invasion; during the long period previously in which the beds were exposed to atmospheric agencies it seems likely that the ores may have weathered for some distance from the outcrop but were planed off by the ice in its southward advance. Yet, the horizontal disposition of the beds has no doubt retarded disintegration. The chief effect of weathering is the removal of calcite which cements the particles of hematite.

The physical constitution of the hematites has already been described and need not be considered in this connection further than to allude to the almost universal presence of oolitic grains in the ores, even those which are apparently of purely fossiliferous nature. The deposition of iron about a nucleus in layer after layer can scarcely be conceived as taking place elsewhere than in bodies of standing water, with the nucleal grains free to roll about and completely in contact with the ferruginous solutions.

The probable conditions prevailing in Clinton time, bearing

[1] C. S. Prosser. The Thickness of the Devonian and Silurian Rocks in Central New York. Geol. Soc. Am. Bul. 4: 91.

upon the formation of the ore beds, have been well stated by Professor Smyth in a paragraph of his paper of which the following is a translation.

By reference to a geological map of the eastern United States, it will be observed that the Clinton beds were deposited in a sea which received the drainage from an extensive area of crystalline rocks. Long continued denundation of these rocks, which are made up in part of iron-bearing silicates and inclose important bodies of magnetite and pyrite, set free large amounts of iron to be carried seaward in solution or suspension. Along the coast of the sea there were in Clinton time extensive swamps and mud flats, evidenced by the frequent surface markings, cracks and tracks of crustaceans and worms found in the shales and sandstones. In other places calcareous fossil fragments accumulated and were rolled about and ground by the waves and finally deposited in shallow water forming shell beaches similar to those of the present day, for example, the coquina on the Florida coast. Most of the iron brought down by land drainage of course would be wasted, but a part would be precipitated to form the ore beds. The precipitation occurred in two ways, thereby giving rise to two ore varieties. Where the waters were collected in partially or completely inclosed basins, the iron was thrown down by slow oxidation and gathered in layer upon layer about the sand grains, thus forming the oolitic ore. The conditions requisite to this method of precipitation obtained apparently over no great areas, so that the oolitic beds are generally of limited extent. Again the ferruginous waters came in contact with the calcareous shell fragments; here the iron was precipitated partly by reaction with the lime carbonate, yet mostly by oxidation, while the lime was carried off in solution by the aid of the carbon dioxid set free. As this process took place while the shells were being rolled about or heaped up in loose aggregates and was chiefly a result of oxidation, the iron took the form of oxid rather than carbonate. It need scarcely be stated that this method of replacement is widely different from the other process of replacement that has been applied to the ores. The progress of the reaction advanced step by step with the accumulation of the fossil fragments. Thus, while the iron is a secondary product as regards the individual particles of ore, it is primary in relation to the ore bed itself. After the ores had thus been collected into loosely aggregated masses of grains and altered fossils, they were compacted into beds and covered by shales, sandstones and limestones. As a result, the grains and fragments rich in iron are frequently surrounded by pure calcite, a circumstance that is far from being opposed to the present theory of ore formation, but rather in line with what one would expect.

View showing small steam shovel and revolving derrick used in removing and loading the ore into the cars. Furnaceville Iron Co., Ontario Center, Wayne co.

The deposition of the iron partly in the form of carbonate is indicated by the fact that the fossil ores quite commonly show a small percentage of this mineral. It is probable, however, that the iron was mostly precipitated as the hydrated oxid. The change from limonite to hematite took place subsequent to the upraising of the beds under the influence of pressure from the overlying strata.

The New York Clinton beds, in common with those of Ohio, Ontario and Wisconsin, were deposited along the northern margin of the interior Mississippian sea, and the ferruginous materials must have been derived largely from the wash of the Precambric land mass on the north and northeast. The New York section has its maximum development in the stretch from Clinton to the west end of Oneida lake where there was apparently an embayment curving around the southwestern border of the Adirondacks. The present outcrop in this part is everywhere within 50 miles at most of the crystalline area. Farther west the beds diminish gradually with the increase of distance from the Adirondack highland, and in the extreme west the materials probably came from the remoter crystalline region of Canada. East of Clinton there is a more rapid thinning of the beds, since the old Appalachian highland that limited the sea in this direction is soon reached. The Pennsylvanian and southern Clinton deposits were laid down on the western shore of the Appalachian highland; their materials were probably gathered from this land mass rather than from the north.

There is an interval of more than 100 miles between the eastern end of the New York belt and the next appearance of the Clinton rocks to the south, which is in central Pennsylvania. It is possible, however, that this gap is due to the overlapping of the higher Upper Siluric members which are represented in eastern New York and pass into Pennsylvania in the vicinity of Port Jervis. A comparison of the faunas of the Clinton in New York and Pennsylvania shows a close relationship that is suggestive of stratigraphic continuity, the buried portion coming to the surface only after it becomes involved in the Appalachian folds.

MINING METHODS

From the beginning of active mining along the Clinton belt, attention has naturally been directed to the northern edge or outcrop of the beds as being the most accessible for develop-

ment. The conditions are well suited for surface work by stripping or trenching throughout much of the stretch from Herkimer to western Wayne county. In places the ore is encountered directly beneath the soil or at most a few feet of glacial materials, while with its flat dip there is often opportunity to extend the field of operations to considerable distances from the outcrop before the overburden becomes excessive. There is still an abundance of ore that can be removed to advantage by open-cut work.

It is quite recently that mechanical methods of excavation have been introduced, and the greater portion of the product in the past has been won by the crude system of hand labor first employed. With the use of portable steam shovels, the cost of taking out the ore has been so reduced that it is now practicable to strip fully twice as much rock as formerly, notwithstanding the material reduction that has taken place in iron ore prices.

An example of good practice in open-cut excavation is afforded by the recent operations of the Furnaceville Iron Co. at Ontario Center. This company has been engaged in working a strip of land lying to the north of that place and extending for over 4 miles in an east and west line. The plan adopted here consists briefly in opening longitudinal trenches, the first along the northern limits of the property, near the outcrop, and the following ones in parallel order progressively with the removal of the ore from the preceding trench. At the present time about 20 feet of overburden is taken off, while in the first cut some 40 rods to the north the ore lay beneath 6 feet of soil and rock. The trench has a width of 60 feet and until recently two shovels were used in its excavation, each cutting 30 feet or one half the whole width. The shovels loaded into buckets which were hoisted by revolving derricks and dumped on the spoil bank opposite the long face of the trench and just beyond the edge of the ore that was being uncovered. The outer shovel worked somewhat in advance. During the last year the trenching has been done by a single 100-ton shovel which removes the rock for a width of about 45 feet, dumping directly on the spoil bank, and then returns to clear the remainder with the aid of a derrick.[1] The shovels and derricks are mounted to run on tracks

[1] Since the above account was written, the methods have been somewhat modified in that a conveyor has been installed, as shown in the accompanying plates. The conveyor consists of a portable structure, with two skips each of 6 cubic yards capacity which receive the rock material from the steam shovel and carry it up the incline (129 feet long) to the dump. This apparatus increases the efficiency of the steam shovel, at the same time enabling the latter to excavate the trench to the full width of 60 feet without return.

View showing steam shovel and conveyor used to remove the overburden from the ore. Furnaceville Iron Co., Ontario Center, Wayne co.

View of trench after removal of overburden and ore. At the base and to the right is shown the ore bed with overburden above. Furnaceville Iron Co., Ontario Center, Wayne co.

set in the trench. The overburden consists of 10 feet or slightly more of limestone, somewhat shaly toward the top, and about the same thickness of soil and glacial material. It is loosened for the shovels by drilling and blasting. The 6-inch holes made by churn drills, extend into the ore for about 3 inches and are 16 feet apart, the first row being 6 feet from the edge of the trench. A layer of limestone, 15 to 18 inches thick, that remains on the ore has to be removed by hand. The ore is then loosened by blasting, after holes 3 feet apart and extending a few inches into the underlying green argillaceous limestone, have been made by steam drills. A small amount of the limestone sometimes adheres to the ore but is readily removed. The ore is broken by sledges into convenient size for handling, after which it is loaded, by means of a 40-ton steam shovel, into the buckets of a derrick and hoisted into cars for shipment. A spur from the Rome, Watertown & Ogdensburg Railroad extends along the trench on the side opposite the spoil bank; it is moved back from time to time with the advance of operations toward the south.

The Fair Haven Iron Co. has pursued a similar plan in opening the property at Sterling Station. The rock is here mostly shale, so that its excavation presents less difficulty than the limestone farther west. Instead of wasting the material in the abandoned part of the workings, the shovel loads into cars which run out on a track at one end and are dumped to the north of the pit. The shale and soil covering has a thickness of from 10 to 20 feet. The material is loosened by blasting in advance of the shovel in the manner above described.

The mines at Clinton furnish the only examples of underground exploitation of the ores in the State. The long-wall method is employed, the same as used in many coal mines. This method admits of complete extraction of the ore in one operation. It is particularly adapted to comparatively thin deposits that have a flat dip. Entrance to the workings may be had either through a shaft, or, if the seam outcrops anywhere, through an adit driven on the level. By taking advantage of the surface features, it has been possible at Clinton to follow the ore from its outcrop and to make use of the slight inclination of the beds in securing natural drainage. The main entries or gangways are run in an easterly or northeasterly direction across the dip. From these, branches turn off at every 100 feet to the working face, which is kept a short distance ahead

of the gangway. As the ore measures 30 inches on the average, approximately 2 feet of the overlying shale is taken down for convenience in working. This material is packed some distance behind the face for roof support, while between the pack and the face wooden posts are placed from 5 to 10 feet apart for further security. As far as possible the posts are removed with the advance of the workings to be again used in the same manner. The bottom of the face is taken out first by drilling diagonally from the top of the ore bed. Upon blasting the lower portion of the ore is loosened and taken out, after which horizontal holes are drilled into the shale and the upper part, including the remainder of the ore bed, is removed. Tracks are laid to the working face and the ore is trammed by hand or by mules to the mine dump outside. The soft character of the Clinton strata is an advantage in this system of working in that it tends to produce a constant and uniform settlement of the ground with the advance of operations. There is thus little or no danger from roof falls. The only drawback seems to be that of occasional creeping of the floor in the gangways which requires attention from time to time.

The few data bearing upon costs that have been obtained would indicate that when the covering does not exceed 20 feet or so the ore can be removed most economically by open cutting. With a 2 foot ore seam, which yields approximately 8000 gross tons to the acre of surface, the cost of stripping and removing the ore under ordinary conditions may be placed at about $1.50 a ton. It has been reported that underground mining has been carried on at Clinton for somewhat less, but here the ore is from 30 to 36 inches thick. Account must be taken also of the expense connected with development work and equipment, which is considerably larger in the case of an underground mine than in surface work.

DESCRIPTION OF ORE LOCALITIES AND MINES

Cayuga county

The outcrop of the fossil ore is encountered near Sterling Station where mining operations were first instituted about 35 years ago and have recently been revived by the Fair Haven Iron Co. Sterling Station lies at the eastern end of the ore belt which stretches across Wayne county. East of this point the ore diminishes rapidly and within a short distance becomes too thin to be workable.

Fair Haven Iron Co. The property of the Fair Haven Iron Co. comprises 280 acres situated just south of Sterling Station

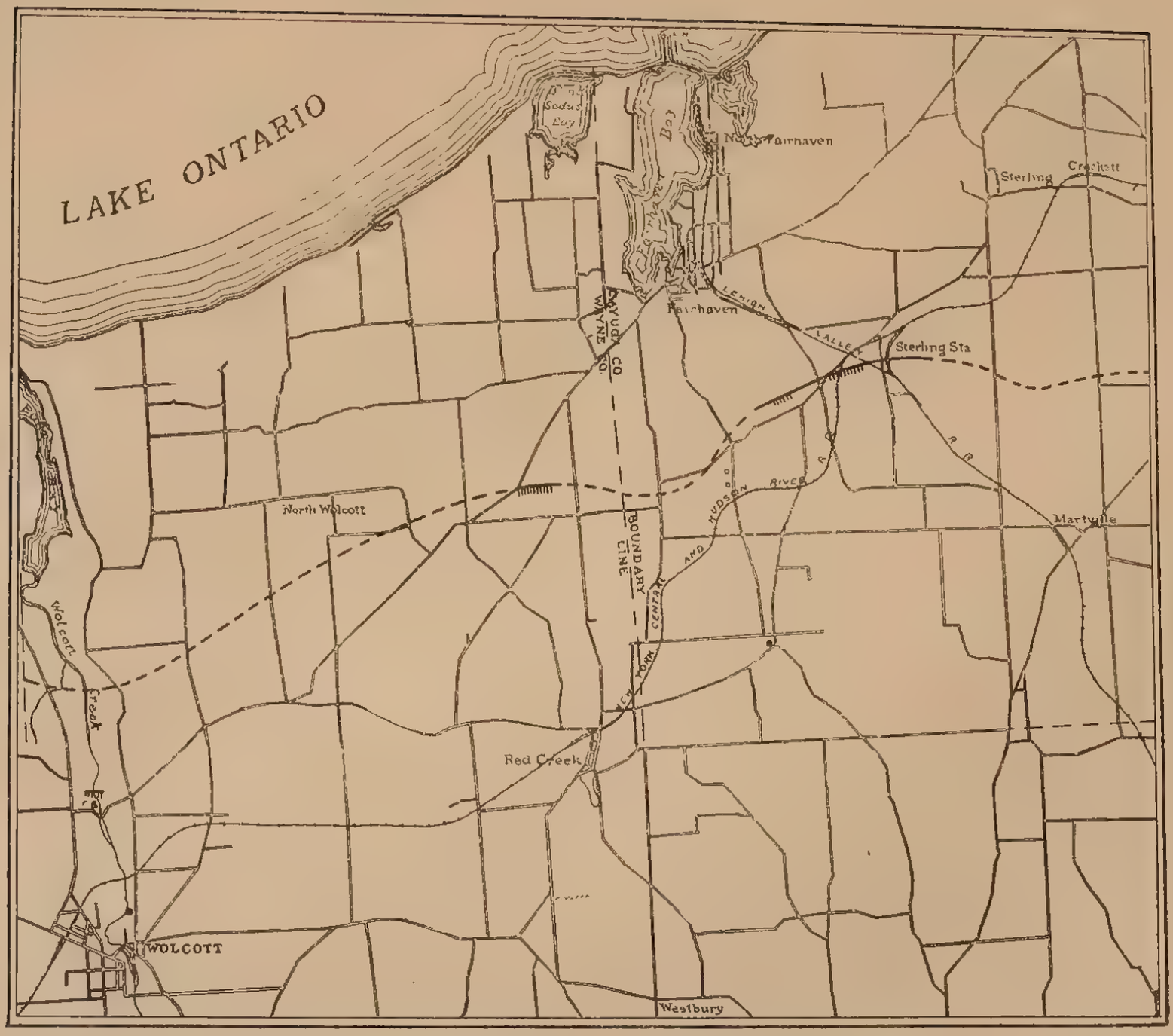


Fig. 3 Sketch map of the Clinton ore belt in Cayuga and eastern Wayne counties. The approximate outcrop of the lower or main ore bed is indicated by the broken line. The map also shows the outcrop of the upper ore seam north of Wolcott and position of the recent test holes. Scale 1 mile to ½ inch

between the Lehigh Valley and New York Central (R. W. & O. branch) railroad lines. The company was organized in 1906. The work done thus far consists in the opening of a trench which begins about 400 yards southwest of the station, near the railroad track, and follows the line of outcrop to the east. The bed is found here beneath 10 to 25 feet of soil and rock. The loose overburden represented by soil and glacial materials varies from 18 inches to 10 feet. A general section involving the ore, made some distance back from the outcrop, with a maximum of covering, is as follows:

MATERIAL	FEET
Soil	10
Shale	55
Limestone	1.5 to 2
Ore	3
Green shaly limestone	5
Medina	10+

The ore as shown in the trench ranges from 30 to 38 inches thick, the average mineable thickness being probably about 30 inches. There is generally a seam of limestone 1 or 2 inches thick in the middle of the ore, while the limestone covering the ore is from 10 to 18 inches thick. Eight feet above the main bed is a thin seam of ore, reaching 4 inches as a maximum. The shale above the ore bed is at times quite compact, but presents no difficulty to excavation after loosening by blasting. It carries one or more layers of limestone which appear at different horizons and are not persistent for any distance, their total thickness amounting to 5 or 6 inches. An analysis of the ore, supplied by Mr W. L. Cumings, showed the following percentages:

Fe_2O_3	49.97
SiO_2	6.01
Al_2O_3	.95
MnO	.47
CaO	13.96
MgO	7.8
SO_3	.11
P_2O_5	.8
CO_2	19.39
H_2O and org	.45
	99.91

Fe	34.98
P	.351
S	.044

The shipments from the property during 1907 are reported to have averaged between 36 and 38% iron.

A spur from the R. W. & O. Railroad extends into the pit from the western end and the ore can be loaded directly on cars for shipment. The rock is run out at the opposite end on a track and dumped on the waste land north of the pit. The excavation has been carried on by means of a 65-ton Marion steam shovel which works down to the limestone capping. The limestone and ore are then removed by drilling and blasting.

Swartout opening. Just west of this property, across the railroad track, is the Swartout opening, which was worked about 35 years ago. The workings are small and the amount of ore taken out could not have amounted to more than a few hundred tons.

Furnaceville Iron Co. A short distance farther west, on the Josiah Gailey farm, ore was mined during the years 1887 and 1888 by the Furnaceville Iron Co. The locality is referred to by Smock[1] who states that the ore occurs in two beds, each about 18 inches thick. It would appear that the two beds are the same as the main bed on the property of the Fair Haven Iron Co. which, as already stated, is divided by a thin seam of limestone. From information obtained locally, the thickness of the ore as mined ranged from 30 to 40 inches. The ore was uncovered by steam shovel. The property is said to be still owned by the Furnaceville Iron Co.

Oneida county

The section of the Clinton belt extending through the towns of New Hartford, Kirkland, Westmoreland and Verona, Oneida co., has afforded most of the ore obtained from the formation in the eastern part of the State. Openings have been made in the ore at intervals all the way from the Oneida-Herkimer county line on the east to Verona Station on the west. Most of the work has been done by open cutting along the outcrop, a method exclusively pursued in the early days of mining, but now abandoned. For some years past operations have been restricted to the properties just

[1] First Report on the Iron Mines and Iron Ore Districts in the State of New York. N. Y. State Mus. Bul. 7. 1889. p. 51.

Entry to the mines of the Franklin Iron Manufacturing Co., Clinton. Red flux bed appears near top, its lower portion being indicated by the iron pipe.

east of Clinton owned by C. A. Borst and the Franklin Iron Manufacturing Co. who obtain the ore entirely by underground mining.

The outcrop of the main ore bed in this region is shown on the map [pl. 12], which reproduces portions of the Oriskany and Utica topographic sheets on the scale of 1 mile to the inch.

The mining industry around Clinton dates back to the beginning of the last century. The first lease for digging ore is said to have been granted in 1797. The Norton mine at the foot of College hill west of Clinton is the site of some of the earliest operations and supplied ore to forges in the vicinity. Charcoal furnaces soon superseded the forges and were operated until the erection of the larger furnaces using anthracite coal. The charcoal plants were located as far away as Taberg and Constantia, while there were others nearer by at Lenox, Walesville, and in the town of Frankfort, Herkimer co. With the opening of the Chenango canal, shipments of ore began to be made to Pennsylvania furnaces. From 1845 to 1850 the Scranton Iron Co. engaged in this business on an extensive scale, shipping the ore from New Hartford and Clinton by boat to Binghamton and then on to Scranton. In 1852 the Franklin Iron Works erected a plant on the site of the present furnace of the Franklin Iron Manufacturing Co., and began operations with an output of 150 tons of pig iron a week. The fuel used was anthracite coal. An additional furnace was built in 1869–70 giving a combined output of about 300 tons a week. The Clinton Iron Co. was organized in 1872 to manufacture iron at Kirkland, just north of Clinton. The furnace was placed in operation in 1872, the ore supply being obtained from Westmoreland. This furnace has been closed down for the last 20 years, while the Franklin furnace has been operated intermittently, depending upon the iron market. Besides the ore used by these furnaces considerable quantities were shipped at one time to Geddes (near Syracuse), Albany and Poughkeepsie. The mining of the Clinton ore for paint manufacture has been carried on by C. A. Borst since 1890. From 5,000 to 10,000 tons are produced each year for that purpose.

Davis opening. This is the most easterly working in Oneida county, being within about a mile of the Herkimer county line. It is also known as the East Hill opening and was once a part of the property owned by the Scranton Iron Co. It was worked for some years by J. G. Egert and afterwards by C. A. Borst. The open-cut excavation extends over several acres beginning a little over a mile east of Washington Mills and extending eastward along the outcrop. The ore is covered by from 6 to 10 feet of soil, with a little shale,

and has a thickness of 22 inches as a maximum, diminishing gradually as one proceeds in an easterly direction. At the upper reservoir on Starch Factory creek, across the county line, the bed is only 10 inches thick. The overlying rocks are shown here up to the red flux bed which has a thickness of 40 inches and is exposed over a considerable area. The ore from the Davis mine was shipped to Poughkeepsie and other points. An analysis given by Putnam shows the following percentages:

Iron	43.76
Phosphorus	1.116

Wells and Ellingwood openings. Continuing westward from the Davis mine, the outcrop of the ore bed comes out into the Sauquoit valley and then turns upstream or southward to a point beyond Chadwicks where it crosses the Sauquoit and follows a nearly northerly course to a point about a mile west of Washington Mills. Some ore has been taken out in the valley near Chadwicks, but there are no extensive excavations until the outcrop is encountered along the highway from Washington Mills to Clinton. In this stretch of about 4 miles the surface is quite level, with only a gradual rise to the south, and a large area of the ore bed can be exploited by shallow workings. The outcrop has already been stripped for much of the distance, as there are many places where the only covering is soil and glacial materials.

The Wells, situated in the eastern part of the town of Kirkland about half way between Washington Mills and Clinton, is an open cut extending along the outcrop for several hundred feet. It was once operated by the Franklin Iron Co. It was idle at the time of Smock's report. The property now belongs to C. A. Borst of Clinton. According to the descriptions of Putnam the ore as worked averaged about 21 inches and was covered by 12 to 15 feet of shale and gravel. An analysis of a sample from 400 tons showed the following percentage of iron and phosphorus.

Iron	46.79
Phosphorus	.64

East of the Wells open cut, there is about 1 mile of the outcrop that has not been exploited, while beyond this interval an opening has been made by C. A. Borst over a small area.

The Ellingwood opening adjoins the Wells on the west. An analy-

930 PARTS OF ORISKANY AND UTICA QUADRANGLES

MAP SHOWING LINE OF OUTCROP OF CLINTON OOLITIC ORE IN PARTS OF ONEIDA AND HERKIMER COUNTIES

sis of the ore made by J. B. Britton and quoted by Putnam gave the following results.

Fe_2O_3	58.2
SiO_2	10.14
S	.51
P_2O_5	2.557
Al_2O_3	3.98
MnO	.2
CaO	6.66
MgO	2.17
H_2O and CO_2	15.14
Undet. and loss	.443
	100.000
Iron	41.05
Phosphorus	1.117

Franklin and Clinton mines. With the sloping of the surface toward the Oriskany valley, the ore beds beyond the Ellingwood opening come out just east of Clinton in a northeast-southwest course at about the 700 foot contour, as shown on the topographic sheet. A large quantity of ore has been removed here by open cutting, the excavations extending nearly a mile on the outcrop, with a width of several hundred feet in places. These workings date back many years. For the last 25 years or more the ore has been mined underground. Altogether an area of about 200 acres has been worked over by mining or stripping, and the ore product must amount to nearly 2,000,000 tons.

The Franklin and Clinton mines are a part of the ore properties owned by the Franklin Iron Manufacturing Co. and have always been operated in connection with the company's furnace at Franklin Springs, 2 miles south of Clinton. They are entered by adit levels that follow the main ore bed in an easterly and southeasterly direction. The advancing long-wall system of mining is employed. From 18 to 24 inches of overlying shale is blasted down with the ore to gain sufficient room for the miners to work. The ore is trammed on cars, holding a little more than a ton, to a loading platform near the mine and is then run over a spur to the Ontario & Western Railroad for shipment to the furnace. Since the rebuilding of the Franklin furnace in 1880 the mines have been intermittently

active, producing about 60,000 tons a year when operated. They were closed down last in November 1907, after a campaign of two years.

The exposures of the Clinton strata at this locality have much interest, as indeed they afford one of the best sections of the formation in eastern New York. The following is the succession as given by C. H. Smyth jr.[1]

MATERIAL	FEET
Calcareous sandstone and thin shale	50+
Non-oolitic ore (red flux)	6
Calcareous sandstone	6
Blue shale and thin sandstone	15
Oolitic ore	2
Shale	2
Oolitic ore	1
Blue shale and thin sandstone	100+

The red flux bed reaches its greatest thickness at this point. The oolitic ore alone is mined. The existence of two oolitic beds in the Clinton section has been generally accepted as a normal condition, but this is not the case. There is convincing evidence to show that the lower seam represents nothing more than a split in the main bed due to a thickening locally of the shale or sandstone parting that is nearly everywhere present. There are few places where the two beds are more than a few inches apart. As a rule the ore in this vicinity really measures from 30 to 36 inches, that is the combined thickness of the two beds, and it has been the recent practice to extract the entire oolitic ore without reference to the intervening rock layer.

The composition of the oolitic ore at this locality is shown by the following analyses.

	1	2	3	4	5
Fe_2O_3	69.17	42.97	79.98	63	71.82
SiO_2	11.57	29.72	9.98	12.63	11.34
Al_2O_3	3.92	4.13	2.4	5.45	3.91
MnO	.19	.37	tr.	.15	1.63
CaO	5.8	8.57	1.54	6.2	3.97
MgO	2.27	1.96	.3	2.77	2.21
S	.28	.837	Nil	.23	Nil
P_2O_5	1.726	1.534	1.239	1.5	2.096

[1] J. F. Kemp. Ore Deposits of the United States. 1896. p. 104.

Furnace of the Franklin Iron Manufacturing Co., near Clinton

	1	2	3	4	5
CO_2	4.75	9.47	4.39	6.15	2.47
H_2O				2.77	
Loss		.439	.171		.554
	99.676	100.000	100.000	100.85	100.000
Iron	48.42	30.08	56.37	44.1	50.68
Phosphorus	.754	.67	.541	.65	.915

Analysis no. 1 was made by C. H. Smyth jr. No. 2 relates to the bottom tier of oolitic ore from the Franklin mine; J. B. Britton, analyst. No. 3 is from the same mine, by J. B. Britton. No. 4 is an average analysis of ore from the Franklin and Clinton mines made by A. H. Chester in 1873. No. 5 is from a sample of ore from the Clinton mine, J. B. Britton, analyst. With the exception of no. 1 which is taken from the report by John C. Smock, the analyses are quoted from Putnam's paper in the Report of the Tenth Census.

The variations in the iron percentages shown by the analyses are extreme and may be ascribed to lack of uniformity in taking samples. The ore as roughly mined will run about 40%; the average return during the last period of operations is stated to have been 40.27%. By removing the rock parting the content can be raised to 45%. The median 12 inches or so of the oolitic bed will assay above 50%.

The red flux bed has been analyzed by E. C. Sullivan[1] with the following results:

Fe_2O_3	30.24
SiO_2	8.71
Al_2O_3	3.67
CaO	20.64
MgO	7.84
SO_3	.15
P_2O_5	.75
CO_2	24.78

[1] Eckel, E. C. The Clinton Hematite. Eng. & Min. Jour. May 11, 1905. p. 897.

Iron	21.16
Phosphorus	.327

Elliott and Butler, or Borst mines. The properties described in the early reports under the names of the Elliott and Butler openings lie just north of the preceding mines along the east-west outcrop of the Clinton. Since their purchase by C. A. Borst, they have been converted into underground mines. They cover an area of 60 acres. The method of mining is the same as practised by the Franklin Iron Manufacturing Co., but the workings are so laid out that natural drainage is secured. The entry is from the west and the ore is trammed by hand to the stock pile where there are facilities for loading directly on cars for shipment. The mining equipment is exceptionally complete while the underground development is such that a large output can be made. An independent spur connects the mine with the main railroad line. Most of the ore heretofore has been sold for grinding into mortar colors and metallic paint, the output for that purpose being much the largest of any hematite mine in the region. The paint ore is shipped with an average of 45% Fe, the quality being somewhat higher than the run-of-mine, since the sandstone parting is removed by cobbing. An analysis of a sample of the ore is reported by Putnam to have given the following percentages:

Iron	45.73
Phosphorus	.554

The oolitic bed measures about 30 inches, with variations of a few inches above and below the average.

Clinton Mills opening. This open cut, also called the Ferman, is situated 2 miles northwest of the preceding mines, on the opposite side of the Oriskany valley. From the mines east of Clinton village, the ore outcrop runs southwest and, forming an upstream deflection as at Sauquoit, crosses the Oriskany at some distance from the surface in the vicinity of Franklin Springs. Continuing north, on the west side of the valley, the ore is first encountered in exposure within the small glen just south of the road that leads up College hill. One mile further north is the Clinton Mills locality, stated by Smock to have afforded some ore for the Kirkland furnace. An

Mining plant of C. A. Borst, Clinton

acre or more of ground was worked by the open-cut method, the operations dating back to the year 1888. On account of the steep valley slope here the overburden increases rapidly away from the outcrop. The section as given by Smock follows:

Glacial drift	18–30 feet
Greenish gray shale	20 inches
Ore bed	24–30 inches
Floor of ferruginous sandstone.	

The ore bed dips at the rate of 3 feet in 100 feet to the southwest, and drainage is not so readily effected as on the east side of the valley. A peculiar feature is the occurrence of slight offsets which displace the bed as much as 6 inches. The ore has the same general character as the Clinton oolitic bed but contains a greater proportion of shaly material.

Norton opening. This adjoins the Clinton Mills property on the north. It is described by Putnam as under operation at the time of his report. The ore is 21 inches thick, with shale covering. An analysis of a sample from 30 tons of the ore is reported by Putnam to have shown:

Iron	39.88
Phosphorus	.665

Openings in town of Westmoreland. The oolitic bed continues north and west into the town of Westmoreland where it has been worked at different places for the supply of the Kirkland and Taberg furnaces.

One was dug on the Pryer and Laughlin farms, about a mile west of Kirkland, for use in the local furnace. The bed is here 18 inches thick. An analysis, quoted from Putnam, shows the following percentages:

Iron	42.9
Phosphorus	.753

About ¾ of a mile north of the Pryer farm, across the small stream that drains into the Oriskany, are the openings on the Derwin farm and a little south of them, across the stream, the Freibergher opening, all of which were made by the Kirkland Iron Co. The ore from the Derwin farm is about 16 inches thick and somewhat

shaly. It was sorted before smelting. A sample of the sorted ore showed:

Iron	40.4
Phosphorus	.693

About ½ mile west from the Derwin farm there are two openings on the adjoining farms of Fred Richer, and a little beyond is another on the Egan farm. The product was partly used in the Taberg furnace. Continuing farther west there are outcrops of the oolitic bed on the farm of Henry Kingsnorth and at Newland's Mills.

Fig. 4. Sketch map of the district about Verona, Oneida co., showing outcrop of the Oneida conglomerate, openings for ore and position of rece. t test boring. The excavations are numbered as follows: 1, Klein, 2. Stevens, 3, Dann, 4 and 5, Cagwin.

Old blast furnace built by the Kirkland Iron Co. and run upon Clinton ore. Kirkland, Oneida co., 2 miles north of Clinton

Openings in the town of Verona. In the interval of about 6 miles from Hecla works to Verona village the oolitic bed disappears, or at least it is nowhere seen in the exposures. The next openings to the west lie just north of Verona village on the Klein farm. The bed is about 1 foot thick and of fossil character, resembling in appearance the red flux bed around Clinton. It lies beneath 5 or 6 feet of earth. The iron content is low, as shown by the following analysis:

Iron	21.85
Phosphorus	.248

West of Verona village, across the New York Central Railroad, is the Cagwin farm, which is mentioned by Putnam as operated under lease by the Onondaga Iron Co. The ore is 15 to 17 inches thick and richer in iron than the eastern part of the same bed. An analysis showed:

Iron	40.27
Phosphorus	.328

The farms owned by M. Stevens, W. E. Dann and Timothy Smith, near by, have furnished a limited amount of ore in the past. There has been no production of ore in this section for some time. The fossil bed seems to have been discovered at an early date, and was worked in places before 1830. The ore was used mainly in the furnaces at Taberg, Constantia and Lenox, while in later years some ore was shipped to Geddes, near Syracuse.

Wayne county

The belt of Clinton rocks crosses northern Wayne county in an east-west direction. The ore outcrop is encountered in the towns of Wolcott, Huron, Sodus, Williamson and Ontario. The mine workings are entirely of open-cut character, situated on the outcrop or near by, where the maximum covering of soil and rock does not exceed 25 feet. The ore belt, so far as it has been located, is shown on the maps facing pages 56 and 70.

The discovery of the hematites in the county dates back to the opening of the last century. Hall records that ore was dug in the town of Ontario during the War of 1812 and carried to Auburn for grinding into paint. Spafford's *Gazeteer*, published in 1824, refers

to active mining operations as carried on in that section for the supply of three local forges and a furnace at Manchester. According to the same authority ore was obtained, also, from the town of Sodus. Hall in 1838 mentioned the existence of workings on the outlet of Salmon creek, town of Sodus, near which a forge was still standing at the time. A furnace had been erected before that date on Bear creek, at the locality now known as Furnaceville, 2 miles north of Ontario village. The furnace was run upon ores taken from the vicinity and continued to operate for many years. About 1869, a new stack having a capacity of 80 tons a day was erected. In the town of Wolcott the manufacture of iron was begun soon after 1820, undoubtedly at the old furnace just north of Wolcott village. The iron after it was converted into castings was hauled to Clyde and shipped to outside points by canal. The last run of iron at this furnace was made in 1869, since which time there has been little or no ore produced in the vicinity. In the town of Ontario mining operations have been carried on more or less steadily from the first discovery.

Openings in the town of Wolcott. The oldest working in this town is that found along the bed of Wolcott creek, 1½ miles north of Wolcott village, near the furnace site. The ore outcrops on both sides of the creek immediately below the soil. It is of fossil character and belongs to the upper ore horizon shown in the record of the test hole put down at Wolcott. It is about 1 foot thick. An analysis quoted from Beck[1] shows the following composition:

Fe_2O_3	51.5
SiO_2	6.0
Al_2O_3	7.5
$CaCO_3$	24.5
$MgCO_3$	7.75
H_2O	2.75
	100.00
Iron	36.05

A second locality, where ore was obtained in the early days, is about 5 miles northeast of Wolcott village, on the course of the little stream called Bear creek. The bed here is 30 inches thick, representing the lower or main seam of ore as developed in this

[1] Mineralogy of New York. 1842. p. 28.

Plate 16

Section of the Clinton beds exposed at Newland's Mills, near Hecla Works, Oneida co. Oolitic ore bed at top, underlain by green shale

region. It has been worked from the outcrop back into the face of a low hill over an area of more than an acre. There has been no work done for the last 40 years. An analysis of the ore is here given.

Fe	38.87
SiO_2	3.45
MnO	.25
S	.018
P	.374

Town of Huron. Hematite is reported to outcrop on lot 339 but has not been worked.

Town of Sodus. There is an old working on Salmon creek, near the mouth, but apparently very little ore has been taken out. Hall states that operations were abandoned before 1838.

Openings in town of Ontario. This township has yielded most of the ore output from the western section of the Clinton belt. The workings extend almost continuously across the whole width of the town, between 5 and 6 miles, and for as much as ¼ mile back from the outcrop. The bed passes into the town of Williamson on the east where it maintains its average thickness for at least 2 miles farther, but has not been opened. The line of workings lies about 3 miles south of Lake Ontario and ½ mile north of the R. W. & O. Railroad tracks. The ore belongs to the fossil variety, averaging about 20 inches thick. It occurs below the Pentamerus limestone, which reaches its maximum in this section of the State.

The Furnaceville Iron Co. owns extensive properties along the ore outcrop from Ontario village westward. At present the strip from Ontario to Ontario Center is under exploitation. The company has been active for many years and its methods of excavation and extraction of the ore have been perfected to a degree rarely seen in such work. At the present time a little more than 20 feet of rock and soil are removed from above the ore bed. The workings are connected by a branch railroad with the main line at Ontario Center. The ore is shipped to Emporium, Pa. Its composition is exhibited by the following analyses, of which no. 1 has been reported by Mr W. L. Cumings and no. 2 has been taken from Putnam's report.

	[1]	[2]
Fe	44.12	41.46
SiO_2	11.74	.....
Al_2O_3	.48	.....

	[1]	[2]
CaO	7.34	.....
MgO	3.76	.....
MnO	tr.	.....
P	.494	.578
S	.028	.....

In the Report of the Tenth Census, Putnam mentions several properties as under operation and shows their location. The properties in order from east to west include the Bennet, Ontario Furnace Co., Hurly, La Frois, Bundy and Ontario Furnace Co., of which all but the first one were active. The principal holdings of the Ontario Furnace Co. have been taken over by the Furnaceville Iron Co., the former company having gone out of existence. The analyses below are from Putnam and refer to ores from these properties: no. 1, Hurly; no. 2, La Frois; and no. 3, Bundy.

	[1]	[2]	[3]
Fe	40.73	42.25	38.36
P	.531	.481	.471

The Ontario Iron Ore Co. is a new producer in this section and began shipments in 1907. The company owns properties lying east of the Slocum road and a little west of Ontario Center.

The Wayne Iron Ore Co. has properties under development near those of the Furnaceville Iron Co., north of Ontario, and also farther west, near the Wayne-Monroe county line. The holdings near Ontario have been tested with a core drill and the ore bed found to range from 18 to 30 inches thick. The ore on the western properties has an average thickness of 18 inches. A series of 15 analyses from samples of the ore represented by the drill cores and test pits distributed over all parts of these properties shows the following average:

Fe	37.85
P	.646

EDUCATION DEPARTMENT
JOHN M. CLARKE
STATE GEOLOGIST

STATE MUSEUM

BULLETIN 123, PLATE 17

PART OF MACEDON QUADRANGLE

MAP SHOWING LINE OF OUTCROP OF CLINTON FOSSIL ORE
THROUGH THE TOWN OF ONTARIO, WAYNE COUNTY

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New York State Education Department

New York State Museum

JOHN M. CLARKE, Director

PUBLICATIONS

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These reports are made up of the reports of the Director, Geologist, Paleontologist, Botanist and Entomologist, and museum bulletins and memoirs, issued as advance sections of the reports.

Director's annual reports 1904–date.

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These reports cover the reports of the State Geologist and of the State Paleontologist. Bound also with the museum reports of which they form a part.

Geologist's annual reports 1881–date. Rep'ts 1, 3–13, 17–date, O; 2, 14–16, Q.

In 1898 the paleontologic work of the State was made distinct from the geologic and was reported separately from 1899–1903. The two departments were reunited in 1904, and are now reported in the Director's report.

The annual reports of the original Natural History Survey, 1837–41, are out of print.

Reports 1–4, 1881–84, were published only in separate form. Of the 5th report 4 pages were reprinted in the 39th museum report, and a supplement to the 6th report was included in the 40th museum report. The 7th and subsequent reports are included in the 41st and following museum reports, except that certain lithographic plates in the 11th report (1891) and 13th (1893) are omitted from the 45th and 47th museum reports.

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Report	*Price*	*Report*	*Price*	*Report*	*Price*
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See first note under Geologist's annual reports.

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Entomologist's annual reports on the injurious and other insects of the State of New York 1882–date.

Reports 3–20 bound also with museum reports 40–46, 48–58 of which they form a part. Since 1898 these reports have been issued as bulletins. Reports 3–4, 17 are out of print, other reports with prices are:

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5	.25	12	.25	20 (" 97)	.40
6	.15	13	.10	21 (" 104)	.25
7	.20	14 (Bul. 23)	.20	22 (" 110)	.25
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Botanist's annual reports 1867–date.

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Separate reports for 1871–74, 1876, 1888–98 are out of print. Report for 1899 may be had for 20c; 1900 for 50c. Since 1901 these reports have been issued as bulletins.

Descriptions and illustrations of edible, poisonous and unwholesome fungi of New York have also been published in volumes 1 and 3 of the 48th (1894) museum report and in volume 1 of the 49th (1895), 51st (1897), 52d (1898), 54th (1900), 55th (1901), 56th (1902), 57th (1903), 58th (1904), 59th (1905) and 60th (1906) reports. The descriptions and illustrations of edible and unwholesome species contained in the 49th, 51st and 52d reports have been revised and rearranged, and, combined with others more recently prepared, constitute Museum memoir 4.

Museum bulletins 1887–date. O. *To advance subscribers, $2 a year or $1 a year for division* (1) *geology, economic geology, paleontology, mineralogy; 50c each for divisions* (2) *general zoology, archeology and miscellaneous,* (3) *botany,* (4) *entomology.*

Bulletins are grouped in the list on the following pages according to divisions. The divisions to which bulletins belong are as follows:

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19 Merrill, F. J. H. Guide to the Study of the Geological Collections of the New York State Museum. 164p. 119pl. map. Nov. 1898. *Out of print.*

21 Kemp, J. F. Geology of the Lake Placid Region. 24p. 1pl. map. Sept. 1898. Free.

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56 Merrill, F. J. H. Description of the State Geologic Map of 1901. 42p. 2 maps, tab. Nov. 1902. 10c.

77 Cushing, H. P. Geology of the Vicinity of Little Falls, Herkimer Co. 98p. il. 15pl. 2 maps. Jan. 1905. 30c.

83 Woodworth, J. B. Pleistocene Geology of the Mooers Quadrangle. 62p. 25pl. map. June 1905. 25c.

84 —— Ancient Water Levels of the Champlain and Hudson Valleys 206p. il. 11pl. 18 maps. July 1905. 45c.

95 Cushing, H. P. Geology of the Northern Adirondack Region. 188p. 15pl. 3 maps. Sept. 1905. 30c.

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